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Do 'red flags' have a scientific basis?

Deep learning
How AI artists could help fleshy humans get creative

Neuroscience
Brain-machine interfaces are closer than you think

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FROM THE EDITOR

Earlier this year, I went to a wedding and caught up with some old friends. We're in our late-30s now, so half of us were chasing rug rats around the reception, while the half with babysitters inhaled wine. Anyone over 30 will know how most of our conversations went: "Kids… Yeah, everything changes… I miss sleep… There's bodily fluids on everything…" But this time, we also had a new subject: how our bodies were falling apart.

My closest friend, who's the kind of guy that takes his bike on holiday, couldn't enjoy the dinner as his cholesterol levels had made his doctor blush. It turns out you *can't* actually eat whatever you want as long as you exercise. Another explained that his back and knees had been ruined by years of long-distance running. His feet, he said, "were a mess". And there was the one person who confessed that he was eating volumes of cheese that were going to haunt him and his wife later that night. It turns out he'd recently been diagnosed as lactose intolerant. The night felt like a series of GP appointments where each patient competed to see who had the worst ailment.

I realise this gradually becomes the norm as you approach 40. Wonky thyroids, new allergies, collapsing arches… the injustice of it all compels you to warn others of the ways your body begins to betray you. It's inevitable. Or is it? We asked health writer James Witts to look into the simplest habits you can adopt to improve your overall wellbeing (find out what they are on p60). No ultramarathons or Peloton workouts here, just small changes that make a big difference… according to science.

Daniel Bennett, Editor

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HAYLEY BENNETT

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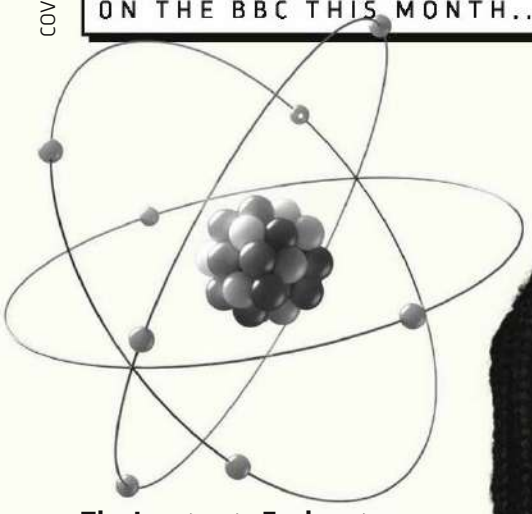
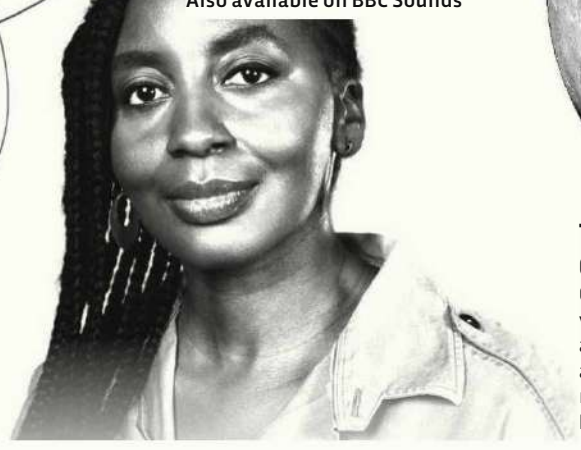
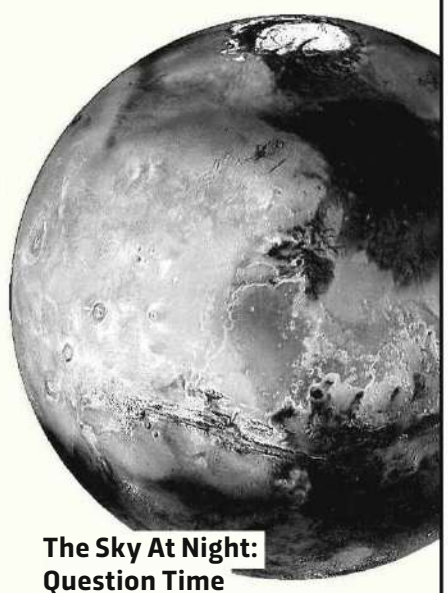


The Language Exchange
What happens when poetry and particle physics collide at CERN? Listen in to see how language can help us reinterpret science.
Radio 4
6 November, 4:30pm
Also available on BBC Sounds



The Conversation: Women Leading A Revolution In Astronomy
Kim Chakanetsa (below) speaks to the women at the cutting edge of space science. Discover how we look for water in space, and what it's like to run the largest radio telescope on Earth.
BBC World Service,
7 November, 11:30pm
Also available on BBC Sounds



The Sky At Night: Question Time
Our new favourite episode of the year where the show's experts answer viewers' questions. Learn about the Artemis and Mars missions, exoplanets and more.
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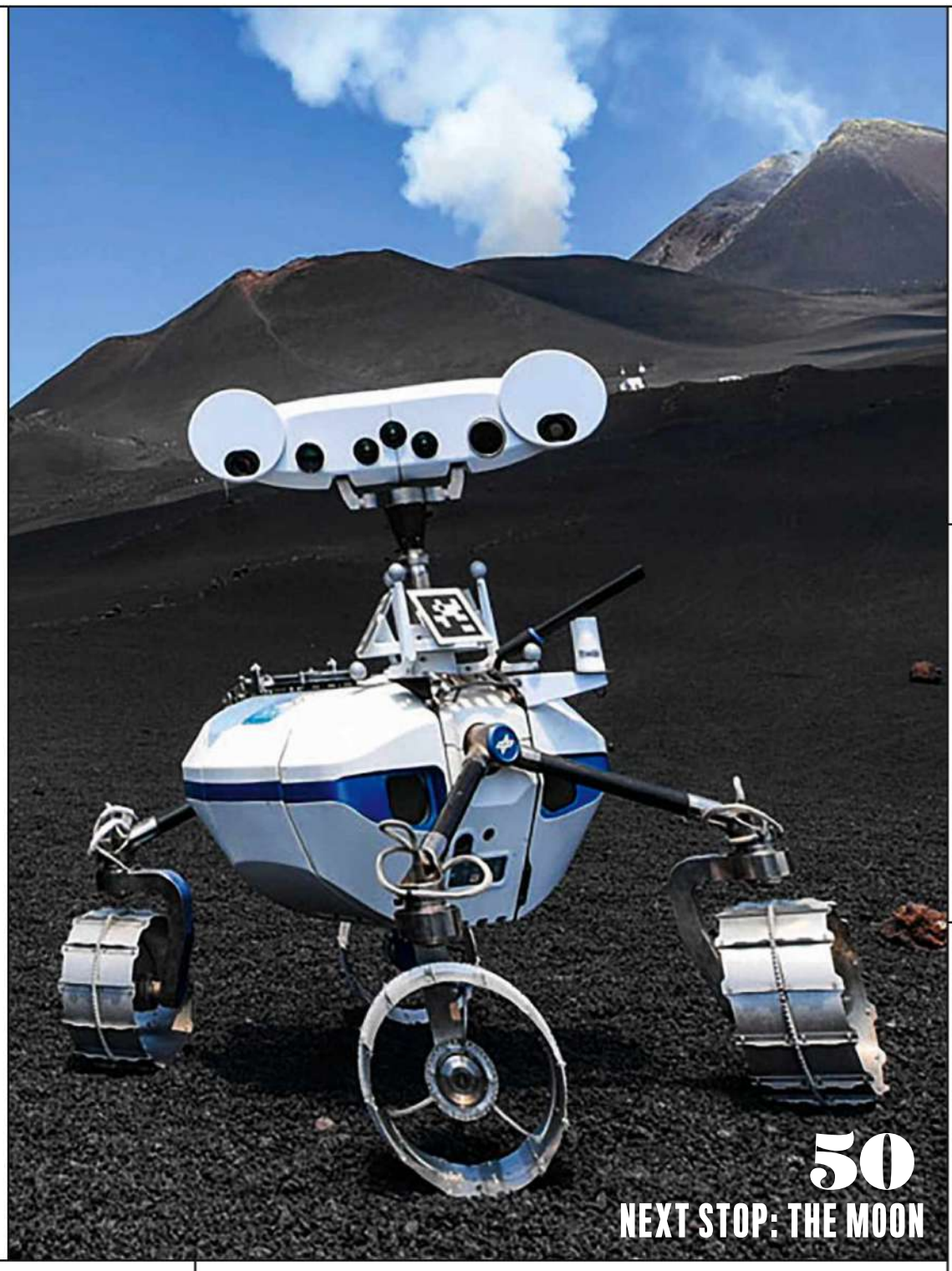

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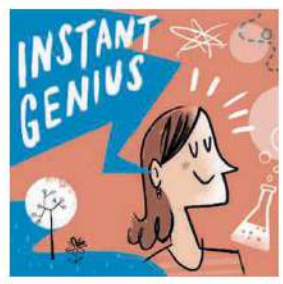

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EYE OPENER

Magic mushrooms

NATTAI NATIONAL PARK, AUSTRALIA

Halloween may have been and gone, but how's this for a spooky scene? The eerily glowing fungi you see here is officially known as *Omphalotus nidiformis*, although it has a rather more apt nickname: the ghost mushroom.

Commonly found growing on dead or dying trees in Australia, the mushrooms are funnel-shaped with gills on the outside. When seen during the day, they're cream coloured with brown and black shading. When night falls, however, they take on a wholly different hue thanks to their bioluminescent properties. They glow green in the dark and while the glow is visible to the naked eye, it's better seen through a camera, as in this image, taken by Callie Chee, which won first place in the Plants and Fungi category of the 2022 Nature Conservancy Photo Contest.

CALLIE CHEE/NATURE CONSERVANCY

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EYE OPENER

Upside-down icicles

SONOMA COUNTY, CALIFORNIA

These might look like ice formations, but they are actually a type of slime mould (*Ceratiomyxa fruticulosa*). They're also tiny, with each branch measuring just a couple of millimetres in length.

This slime mould can be found growing all over the world, typically covering decaying wood like a layer of frost. But ice isn't the only thing it can be mistaken for, because slime moulds used to be classified as fungi. You can see why – they grow on rotting plant material, they release spores to reproduce, they even have mould in their name. But slime moulds are actually classified as protists, and there are at least 1,000 known species.

The branches you can see here are part of the mould's reproduction process. Spores form on tiny stalks that cover the upper portion of each branch, before being released to start a new patch elsewhere.

TIMOTHY BOOMER/WILDMACRO.COM

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CONVERSATION

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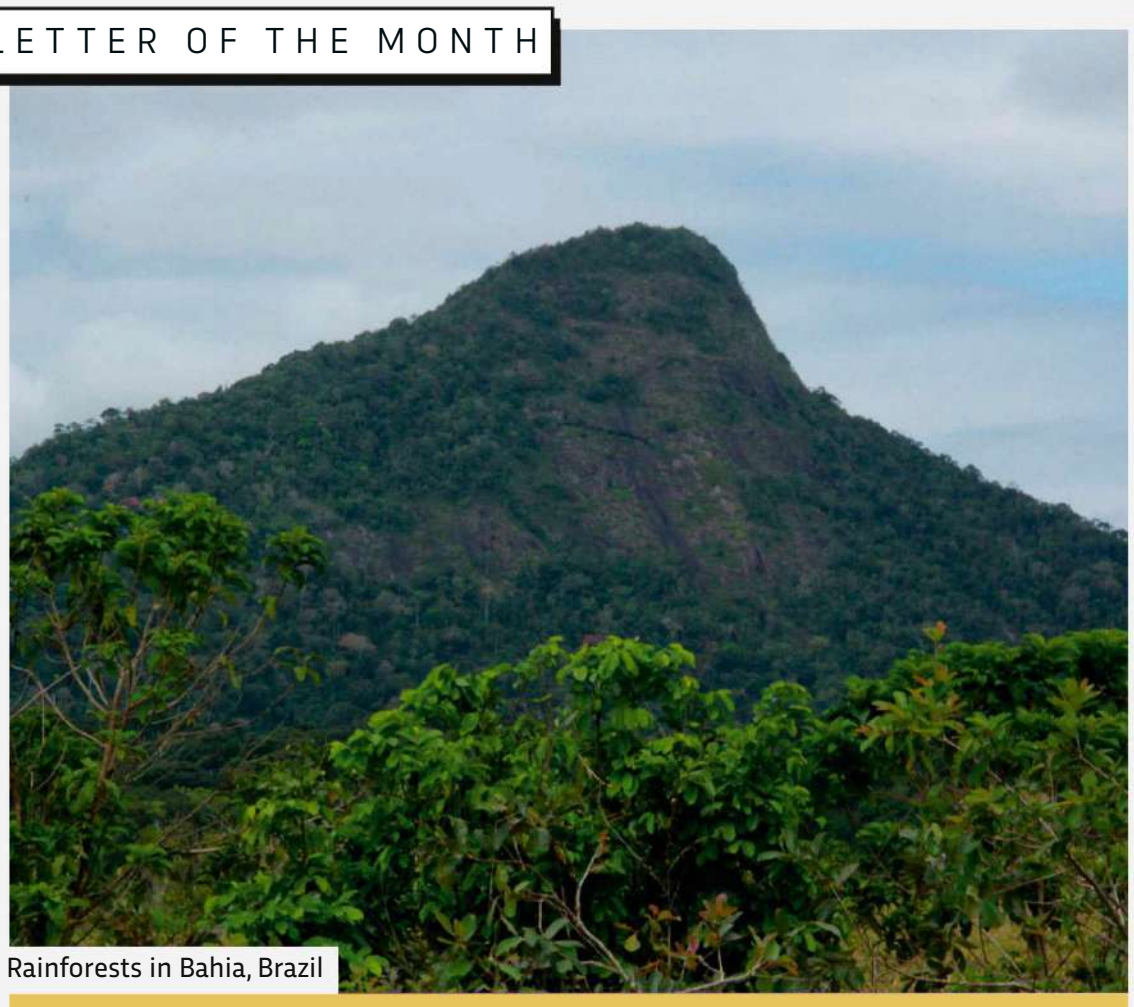
LETTER OF THE MONTH



Rainforests in Bahia, Brazil

Britain's rainforests

Britain's temperate rainforests along the western (Atlantic) coast (September, p38) bear considerable similarity to the eastern coastal Atlantic forest reserves of Brazil, in the states of Bahia and Espírito Santo. These are World Heritage listed because of their biodiversity. Although in the southern hemisphere, it is likely that both coasts of the Atlantic had extensive forests, and may have originated from a similar ancient forest. There seems to be a good case for nominating Britain's temperate rainforests for similar recognition to increase their protection.

Roger Webber, Argyll, Scotland

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a pair of **Edifier W240TN earbuds.** The earbuds come with a stylish industrial-chic design, featuring a gunmetal finish inspired by a robust piston head – think *RoboCop* meets *Blade Runner*. But they don't just look cool, they come with active noise-cancelling tech, over eight hours of playtime, three different sound modes (classic, dynamic or customised), plus they're water-resistant, so they can power you through your workout. **amazon.co.uk**

Star stuff

My dad used to say, "you can't get something outta nothing". Does this mean that every single one of the tiniest particles that make up our surroundings has previously existed in one form or another, and in a different part of the Universe, before being re-assembled into all the forms of life, nature and structures that we see around us? Whatever the answer, how mind-bogglingly beautiful and incredible is life and the planet we live on?

Paul Roberts, Övertorneå, Swedish Lapland

The Big Bang and the expansion of the Universe make the question of the conservation of energy in cosmology a bit tricky, so whether or not something can come from nothing is still a topic physicists argue about. But if we don't worry too much about the *very* beginning, and we just look at the particles that make up our bodies and our surroundings, then it is true that all the particles we're made of have existed in one form or another since particles began to exist in the cosmos! Every atom that isn't hydrogen or helium or a sprinkling of other light elements was formed through some violent process occurring during the life or death of a star – but the protons and neutrons and electrons have all been around since the start,

Connections with gran and granddad are vital, says Bernard Brignall

"WITH BETTER POLITICAL AND ECONOMIC LABOUR SUPPORT, IT WOULD BE EASIER TO EMBRACE THE DISRUPTION BROUGHT ON BY NEW AI TOOLS"

DR KATE DARLING, P30

An illustration of the train-based CO_2-capture system that was covered in the August issue

ALAMY, GETTY IMAGES, CO2 RAIL COMPANY

with the possible caveat that some conversion between matter particles and photons (light particles) may have occurred. Every calcium atom in your bones was assembled from lighter elements by a dying star, and every hydrogen atom was forged in the Big Bang!
Dr Katie Mack, cosmologist

Don't forget Grandma

I just read your article about men being lonely (October, p68), and I was wondering about intergeneration interaction. I found that when going through my teenage years, I was closer to my maternal grandmother than my own parents. Not only would I spend a lot of time with my grandmother, but I could talk to her more freely. Also, if my mother wanted to know where I was, or what I was doing, she would invariably ring my grandma. I believe that bonds that skip a generation are far stronger, because they give a sympathetic ear and are not judgmental. Wisdom is also freely given and listened to more receptively.
Bernard Brignall, via email

A neat solution?

As a car lover, I'm often torn between the excitement a high-performance engine provides and the guilt of adding more carbon dioxide to the atmosphere. With this in mind, synthetic fuel is something I'm hoping will provide less guilt in the future. After reading your article about how trains could suck CO_2 out of the air as they cross the country (August, p18), I wondered if this collected CO_2 could be used to produce synthetic fuel, rather than storing it in rock formations?
Greg Watson, Cambridgeshire

We spoke to Prof Geoffrey Ozin, who led the research, and the answer is a resounding yes!
Alice Lipscombe-Southwell, managing editor

THE TEAM

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DISCOVERIES

“This is a watershed moment for planetary defence”

Bill Nelson, NASA administrator **p20**

NEUROSCIENCE

BRAIN CELLS PLAY *PONG*

Neurons grown in a Petri dish learn to play classic video game **p14**

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Pet pooches can pick up the scent of people’s anxiety **p16**

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‘Super-sized’ brain cells help some people stay sharp into old age **p17**

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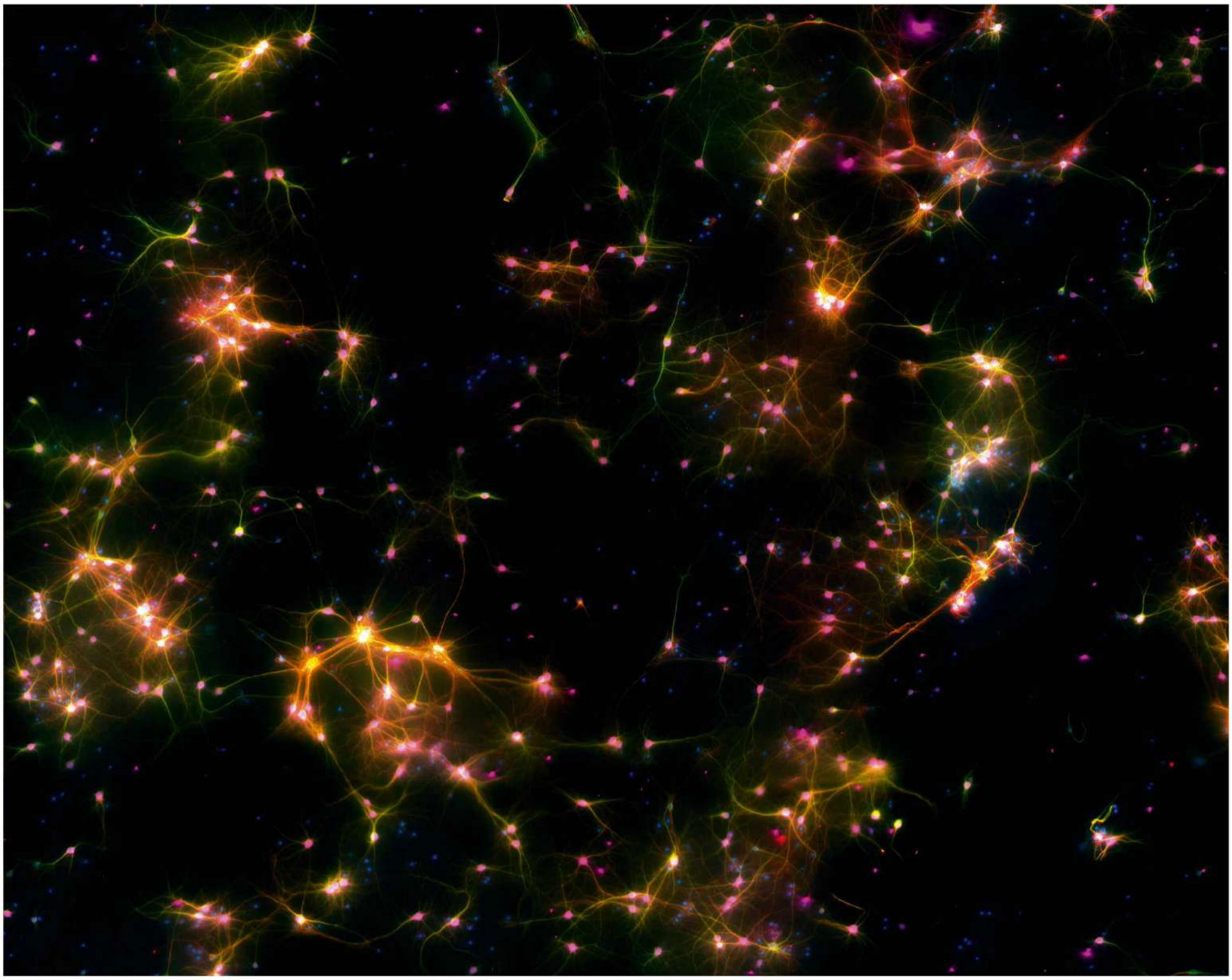
Wingless, cat-sized fossil found to be early relative of flying reptiles **p24**

Collision course: NASA’s asteroid-diverting DART spacecraft has pushed Dimorphos off its original orbital path

NASA/JPL



NEUROSCIENCE

SCIENTISTS TEACH BRAIN CELLS IN A PETRI DISH TO PLAY *PONG*

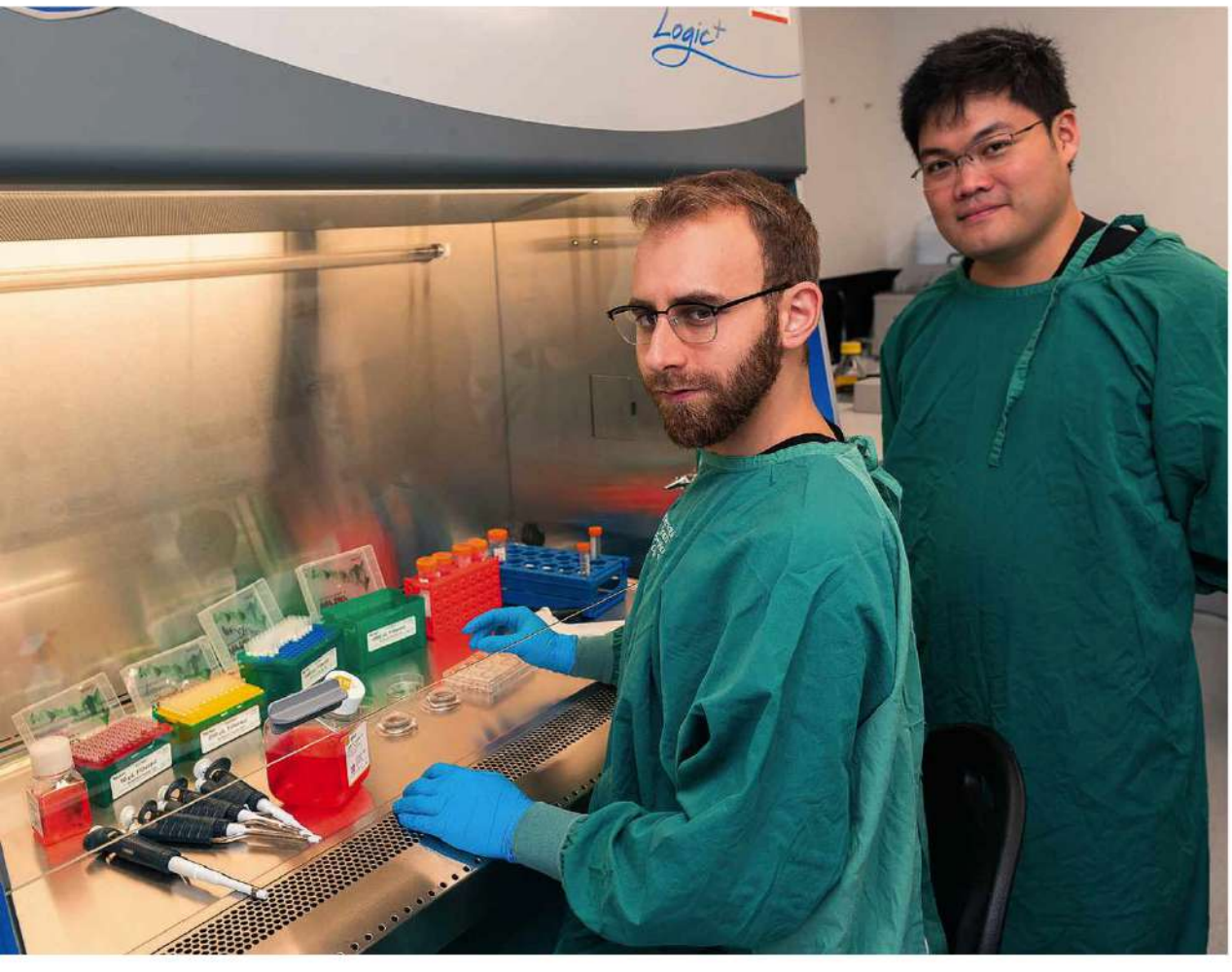
Next they plan to get the brain cells drunk, in a bid to learn more about the effects of drugs on the brain

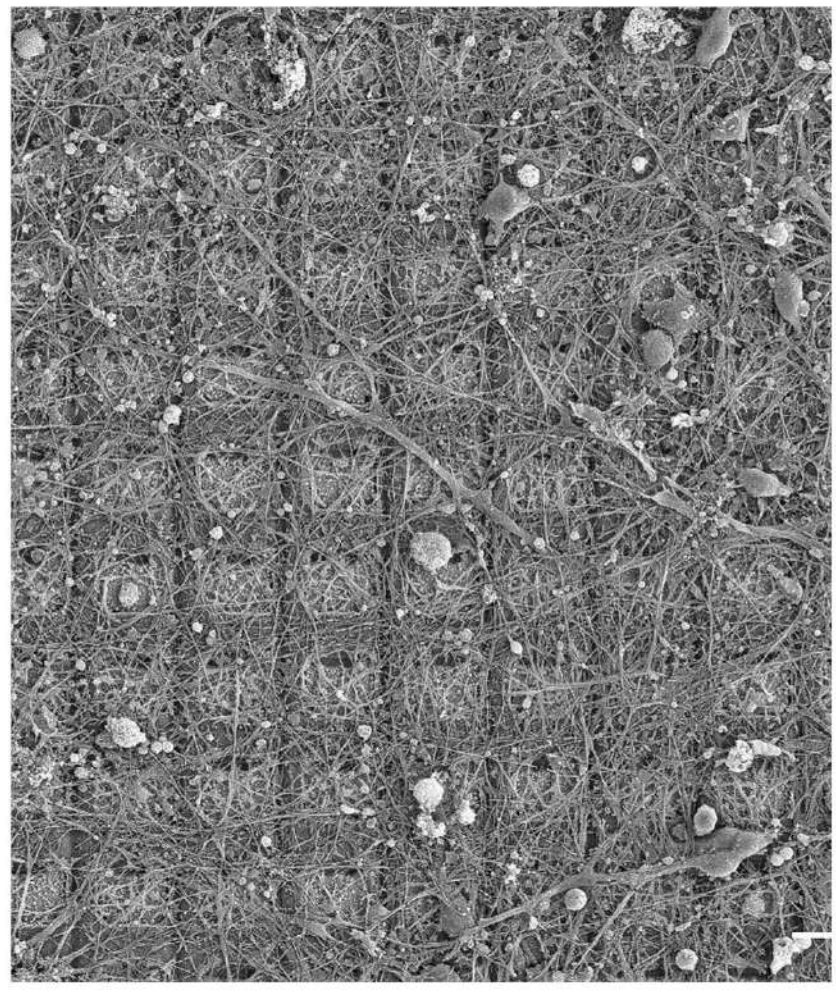
ABOVE Artificially coloured neural cells seen under a microscope. Neurons are shown in purple and green

Since its release in 1972, the table tennis-themed video game *Pong* has provided hours of entertainment to players of all genders, ages and walks of life. Now, thanks to an international team of neuroscientists, it can add a Petri dish containing 800,000 living brain cells to that list.

Named DishBrain, the 'player in a Petri' provides evidence that brain cells can display signs of intelligent behaviour, even when they're not part of a fully formed organ.

To create DishBrain, the team used human brain cells derived from stem cells, as well as brain cells harvested from embryonic mice. The cells were then grown in a Petri dish on a special type of silicon chip hooked up to a system that enabled them to learn to play *Pong*.





A signal indicating the location of the ball on screen was fed to DishBrain through the chip it was sitting on. When the ball was on the left, electrodes on the left of the chip fired, and vice versa. Meanwhile, the ball's distance from the paddle was indicated by the signal's frequency.

Electric probes were then used to give DishBrain feedback that got stronger the closer it could move the paddle towards the ball.

"The beautiful and pioneering aspect of this work rests on equipping the neurons with sensations – the feedback – and, crucially, the ability to act on their world," said Prof Karl Friston, a theoretical neuroscientist at University College London and part of the research team.

"Remarkably, the cultures learned how to make their world more predictable by acting upon it. This is remarkable because you can't teach this kind of self-organisation, simply because, unlike a pet, these mini brains have no sense of reward or punishment."

While previous experiments have successfully monitored the activity of neurons mounted on chips, DishBrain is the first example of them being stimulated in a meaningful way, the researchers say.

DishBrain could enable scientists to conduct experiments using real brain cells rather than computer models when researching neurodegenerative diseases and the effects of potential medicines. "The translational potential of this work is truly exciting: it means we don't have to worry about creating 'digital twins' to test therapeutic interventions," said Friston.

ABOVE Lead DishBrain researcher, Dr Brett Kagan (seated in foreground)

ABOVE RIGHT A scanning electron microscope image of the DishBrain neural culture growing on the silicon chip

"We now have the ultimate biomimetic 'sandbox' in which to test the effects of drugs and genetic variants"

"We now have, in principle, the ultimate biomimetic 'sandbox' in which to test the effects of drugs and genetic variants – a sandbox constituted by exactly the same computing, that is, neuronal, elements found in your brain and mine."

Before they can get started on investigating the effects of medicines, though, the neuroscientists want to see what effect alcohol will have on DishBrain.

"We have shown we can interact with living biological neurons in such a way that compels them to modify their activity, leading to something that resembles intelligence," said lead researcher Dr Brett Kagan, chief scientific officer of biotech start-up Cortical Labs, in Melbourne, Australia.

"We're trying to create a dose response curve with ethanol – basically get DishBrain 'drunk' and see if it plays the game more poorly, just as when people drink."

PSYCHOLOGY

DOGS REALLY CAN TELL WHEN WE'RE STRESSED

Pet pooches can sniff out the scent of stress hormones in our sweat and breath

As any dog owner will tell you, their canine friend can tell when they are feeling stressed. Now, researchers at Queen's University Belfast have demonstrated that they're right: dogs *do* know when we're stressed, because they can smell it.

The finding follows previous studies on the canine sense of smell, which have shown that dogs are able to sniff out cancer and COVID-19 in human sweat.

To make this latest discovery, the team recruited four dogs – Treo, Fingal, Soot and Winnie – from domestic homes in Belfast, along with 36 human volunteers. They set the humans a complicated maths problem designed to raise their stress levels and took samples of their sweat and breath before and after they attempted to solve it. The researchers monitored the volunteers throughout the experiment and only took the second sample when they detected increases in their blood pressure and heart rate – both clear indicators of stress.

Meanwhile, the dogs were trained to pick out specific scents from a line-up.

The team then presented each of the dogs with a selection of scents, including a volunteer's relaxed and stressed samples, to see if the dogs could distinguish between them. All four of the dogs were able to correctly identify each volunteer's stressed sample, even though they had never met them before.

"The findings show that humans produce different smells through our sweat and breath when we're stressed and dogs can tell these apart from our smell when relaxed – even if it's someone they don't know," said researcher Clara Wilson, a PhD student in the school of psychology at Queen's University.

"The research highlights that dogs don't need visual or audio cues to pick up on human stress. This is the first study of its kind and it provides evidence that dogs can smell stress from breath and sweat alone, which could be useful when training service and therapy dogs.

"It also helps to shed more light on the human-dog relationship and adds to our understanding of how dogs may interpret and interact with human psychological states."

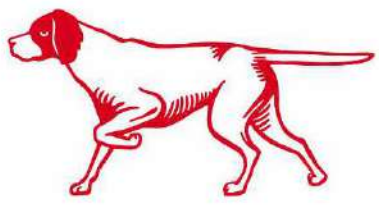
ON THE PODCAST
Listen to an episode of the *Instant Genius* podcast about medical detection dogs at **bit.ly/detection_dogs**

LEFT Soot, one of the dogs in the study, checks out the odours from a selection of sweat samples taken from the volunteers

QUEEN'S UNIVERSITY BELFAST, GETTY IMAGES

SCENTS AND SENSE-ABILITY

Dogs are famous for their incredible sense of smell. Here are just a few of the factors that make their noses so sensitive...



SMELLING IN STEREO

Each of a dog's nostrils is able to smell independently. This allows them to determine which direction a particular scent is coming from.

220 MILLION

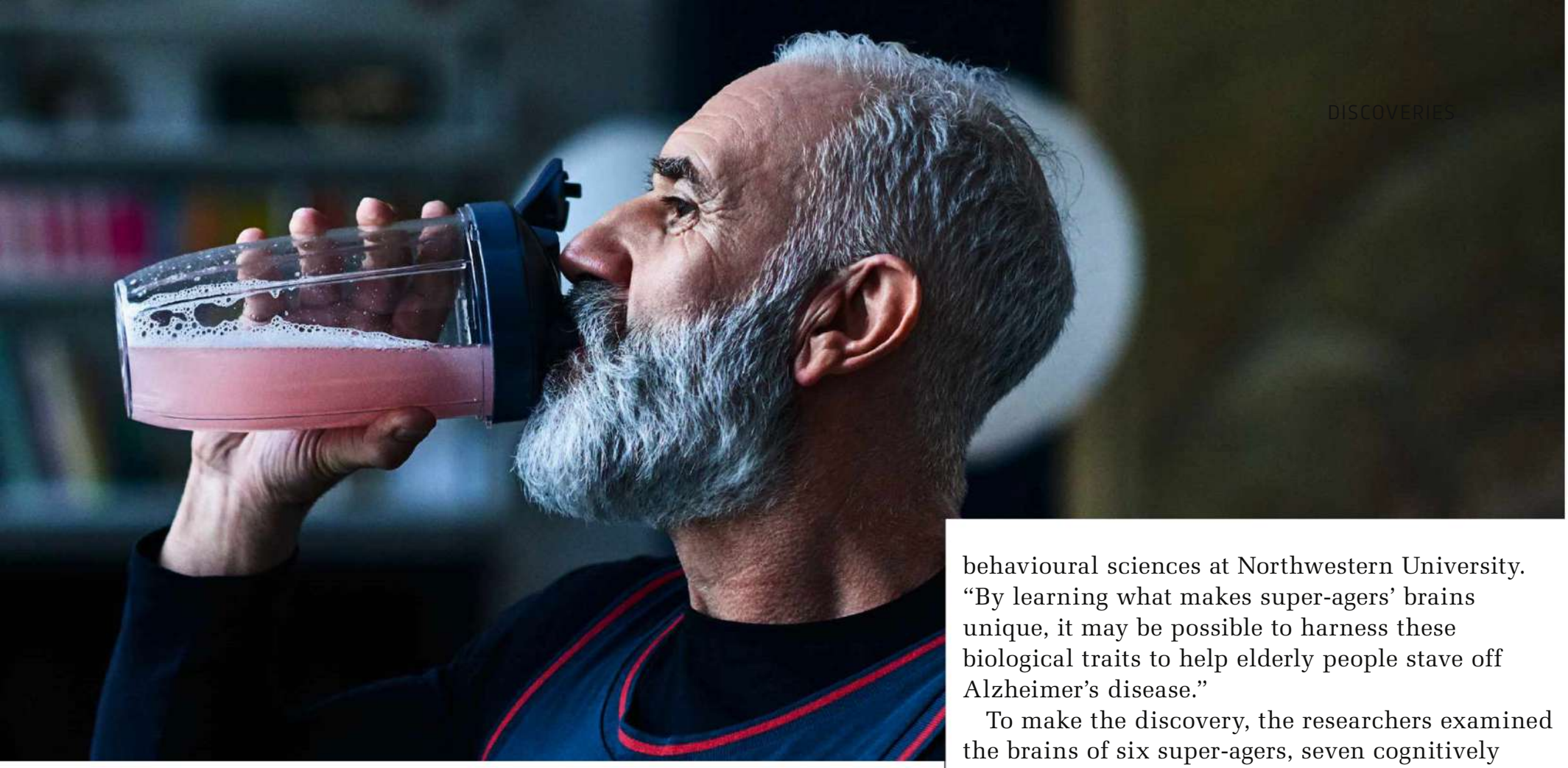
A NUMBERS GAME

Our canine companions have around 220 million scent receptors in their noses. Humans have just five million.

10,000

SENSITIVE TO SCENTS

With so many more receptors in their noses, a dog's sense of smell is around 10,000 times more sensitive than a human's.



NEUROSCIENCE

SUPER-SIZED NEURONS IN THE AREA OF THE BRAIN RESPONSIBLE FOR MEMORY KEEP SUPER-AGERS SHARP

Some of us stay mentally sharp well into our 80s and it could be due to the size of our brain cells

Super-agers have long puzzled scientists. Despite being in their 70s and 80s, they have the physical ability and cognitive function of people much younger.

Now, researchers at Northwestern University in Illinois may have discovered one of the reasons super-agers are able to stay so mentally sharp: the neurons in their entorhinal cortex, the part of the brain responsible for storing memories, are much larger than those of their cognitively average peers.

Furthermore, these neurons show no sign of tau tangles, the abnormal accumulations of protein that collect inside neurons and limit the communication between them, which are a tell-tale sign of Alzheimer's disease.

"To understand how and why people may be resistant to developing Alzheimer's disease, it's important to closely investigate the postmortem brains of super-agers," said lead researcher Tamar Gefen, an assistant professor of psychiatry and behavioural sciences at Northwestern University. "By learning what makes super-agers' brains unique, it may be possible to harness these biological traits to help elderly people stave off Alzheimer's disease."

To make the discovery, the researchers examined the brains of six super-agers, seven cognitively average elderly individuals, six young individuals and five individuals in the early stages of Alzheimer's disease.

"The remarkable observation that super-agers showed larger neurons than their younger peers may imply that large cells were present from birth and are maintained structurally throughout their lives. We conclude that larger neurons are a biological signature of the super-ageing trajectory."

The researchers concentrated their studies on the entorhinal cortex as it's one of the first locations to be affected by Alzheimer's disease. The entorhinal cortex is made up of six layers of neurons stacked on top of one another, and the second of these layers is known to be a particularly important hub that receives information from other memory centres in the brain.

The neurons that form this second layer were found to be bigger in super-agers than in all of the other groups in the study, even those who were 20 to 30 years younger. They were also found to be free from tau tangles.

"In this study, we show that in Alzheimer's disease, neuronal shrinkage [atrophy] in the entorhinal cortex appears to be a characteristic marker of the disease," Gefen said.

"It's important to closely investigate the postmortem brains of super-agers"

"We suspect this process is a function of tau tangle formation in the affected cells leading to poor memory abilities in older age. Identifying this contributing factor – and every contributing factor – is crucial to the early identification of Alzheimer's, monitoring its course and guiding treatment."

The researchers are now planning further studies to try and figure out why super-agers have such large neurons.

BIOLOGY

NEW ANTIBIOTIC FOUND IN POTATO BACTERIA

The discovery could help in the fight against antibiotic resistance

An international research team has discovered a new antibiotic in potatoes. Dubbed solanimycin, the discovery suggests that plant-based microorganisms might represent a rich source of antibiotics to which bacteria are not yet resistant.

Antibiotic medications are becoming increasing ineffective against bacterial infections, as their widespread use has enabled bacteria to evolve resistance to them. But most of the antibiotics prescribed today are derived from microbes found in soil and there others to be found elsewhere.

"We have to look more expansively across much more of the microbial populations available to us," said Dr Rita Monson, a microbiologist from the University of Cambridge and a member of the team that found solanimycin.

Solanimycin is produced by the bacterium *Dickeya solani* and is an effective treatment against a wide range of crop-killing fungi. In lab tests, solanimycin was also effective against *Candida albicans*, a fungus that can cause serious infections in humans.

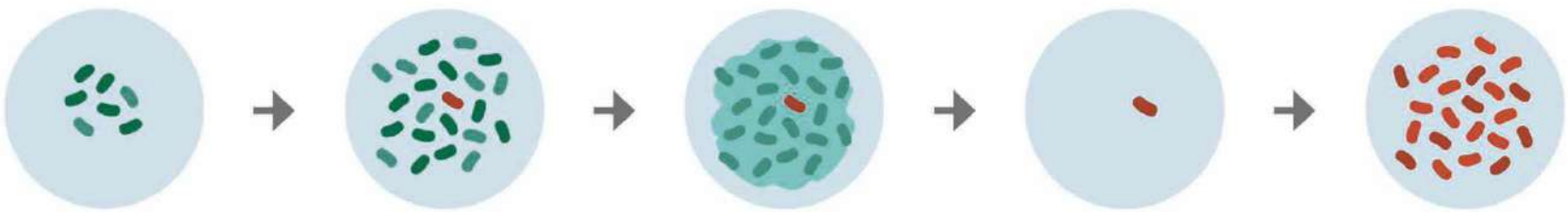
The team has started working with chemists to learn more about solanimycin and to better understand how it works.

"Our future steps are focused on trying to use this antibiotic for plant protection," said team member Dr Miguel Matilla, from Spain's Estación Experimental del Zaidín.

Bacteria have been evolving to resist the effects of antibiotics ever since Alexander Fleming discovered penicillin in 1928. If bacteria resistance continues to evolve, it's estimated that all currently known antibiotics might become ineffective within decades. Such an outcome would be devastating. According to a report commissioned by the UK government, the number of deaths antibiotic resistance would lead to could cause the world's population to fall by 300 million by 2050.

"We have to look more expansively across more of the microbial populations available to us"

How antibiotic resistance arises



A bacterium divides to become a bacterial population

During division, one bacterium undergoes a mutation that results in antibiotic resistance

When an antibiotic is added, all the sensitive bacteria are killed

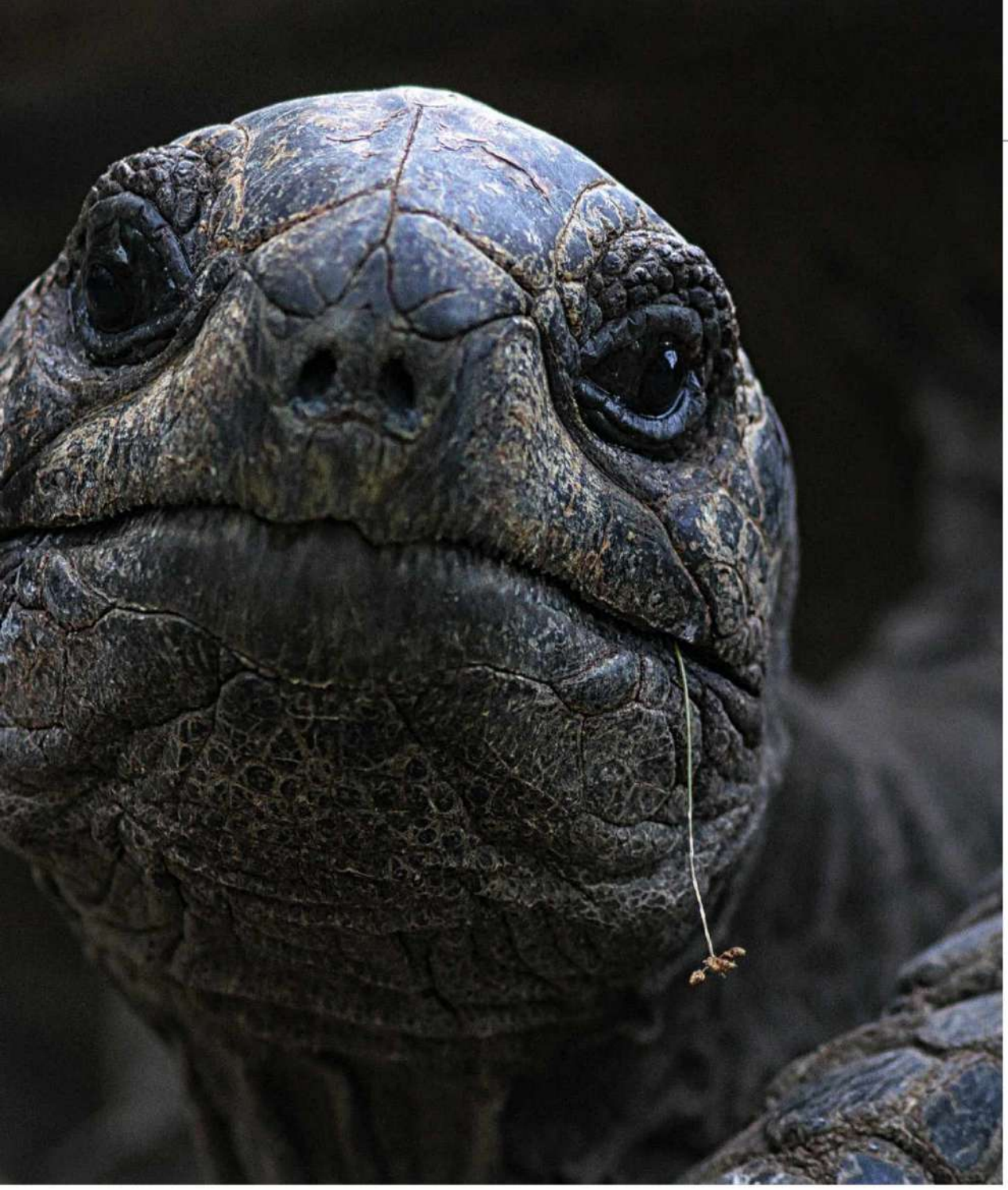
The antibiotic-resistant bacterium survives, however

The resistant bacterium divides, forming a population of resistant bacteria

LEFT A potato infected with *Dickeya solani* bacteria

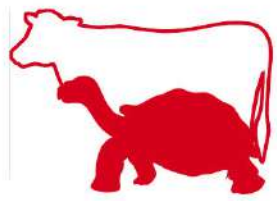
ABOVE Aldabra tortoises are herbivorous, consuming a wide variety of grasses, plants and shrubs

AHDB WEB, DENNIS HANSEN, GETTY IMAGES



THE ALDABRA GIANT TORTOISE

The Aldabra giant tortoise can grow to a weight of up to 300kg – half the size of an average dairy cow. Its shell can measure more than 1.2m from front to back.



250 They are incredibly long-lived. They typically make it into their 100s but one animal that died in a Calcutta zoo in 2006 was reportedly 250 years old. If this is true, it would make it the oldest land vertebrate ever recorded.

Females lay clutches of 10 to 25 eggs between February and May. After incubating for eight months, the hatchlings emerge between October and December.

25

ZOOLOGY

GENOME-SEQUENCING PROJECT MAY SAVE ONE OF THE WORLD'S LAST SURVIVING SPECIES OF GIANT TORTOISE

The Aldabra giant tortoise is classed as vulnerable, meaning the species is at high risk of going extinct in the wild

Fossil records show that giant tortoises were once widespread. These days, thanks to predation by invasive species such as dogs and cats, and grazing competition from cattle, there are just two species left: the Aldabra giant tortoise, which lives on the Aldabra Atoll in the Seychelles, and the more famous Galápagos giant tortoises, of which there are a number of subspecies. These giant tortoises are considered to be vulnerable to extinction or critically endangered.

Now, an international research team has made a breakthrough that could help halt the decline of at least one of the species, after producing a highly detailed genome sequence of the Aldabra giant tortoise.

The discovery will help researchers' efforts to breed the animals and strengthen their numbers, while also allowing them to study their biology and anatomy in greater detail.

"Genomic information is important for breeding efforts in zoos to maintain the genetic diversity that is present in the wild," said lead researcher Dr Gözde Çilingir from the University of Zürich.

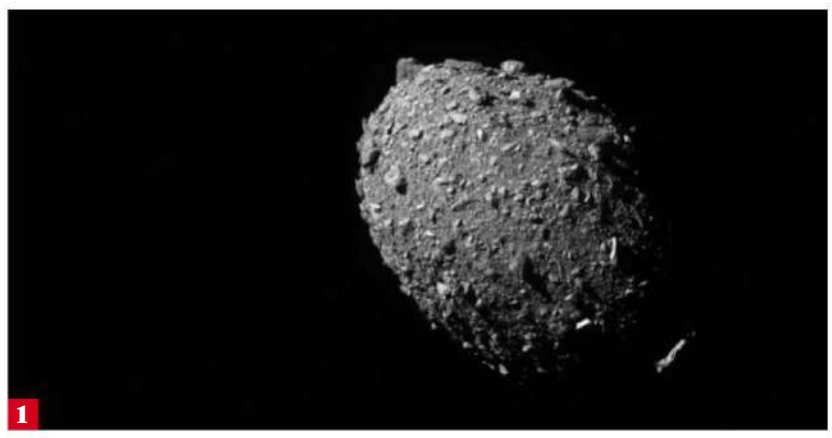
"We revealed that most of the genome is similar to other known genomes of Testudines [the order comprising turtles and tortoises]."

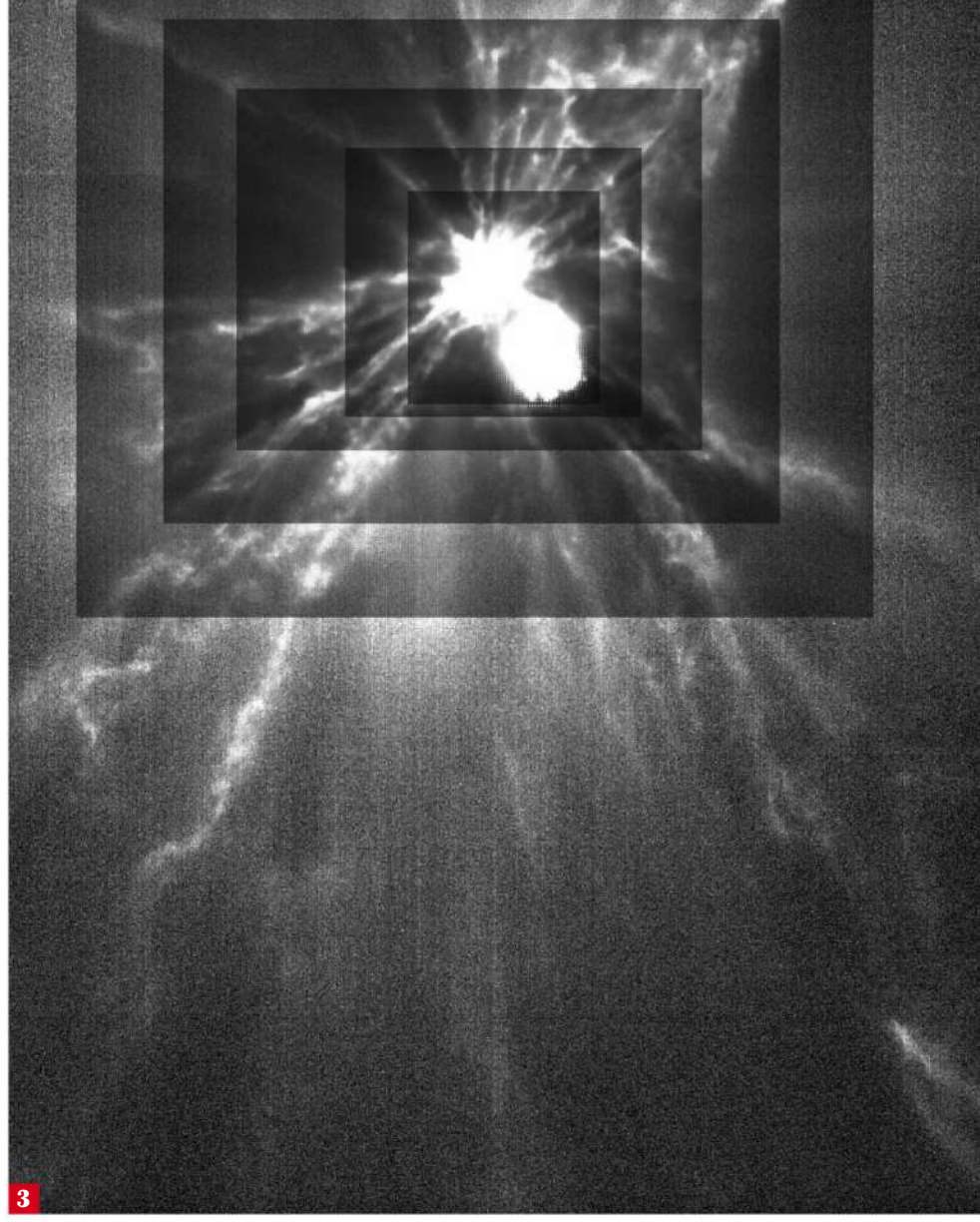
The genome produced by the team is the most detailed to date and accurately shows the sequence of more than two billion genetic letters. Information of this accuracy and detail will enable researchers to more reliably track genetic variation in wild and captive tortoises.

To test drive the technique, the team sequenced the genomes of 30 tortoises living in the wild in Madagascar and two currently homed in Zürich Zoo.

By comparing this data with the reference genome, they were able to determine where the zoo-housed animals originally came from.

"Tortoise species are evolutionarily closely related to each other, and therefore our data will be tremendously helpful not only for the Aldabra tortoise but for all east African and Madagascan tortoises," said Çilingir.





SPACE

NASA DEFLECTS ASTEROID BY SMASHING SPACESHIP INTO IT

The mission is a major step forward in protecting the Earth from potentially devastating asteroid impacts

ABOVE
1. The target asteroid, Dimorphos

2. Last complete image taken by DART, two seconds before impact

3. Streams of material ejected from the asteroid after the impact. Each rectangle represents a different layer of contrast to make it easier to study the impact process

On 27 September, NASA's Double Asteroid Redirection Test (DART) spacecraft scored a direct hit on its target, Dimorphos. Now, after collecting and analysing the data, the space agency has announced that the collision has successfully nudged the asteroid off its path.

The success marks the first time humanity has altered the motion of a celestial object and is a major step forward in defending the Earth from potentially devastating asteroid impacts.

"All of us have a responsibility to protect our home planet. After all, it's the only one we have," said NASA administrator Bill Nelson.

"This mission shows that NASA is trying to be ready for whatever the Universe throws at us. NASA has proven we are serious as a defender of the planet. This is a watershed moment for planetary defence and all of humanity, demonstrating commitment from NASA's exceptional team and partners from around the world."

Following the impact, telescopes based on Earth were trained on the asteroid to determine how much its orbit around its companion asteroid, Didymos, had changed.

The DART investigation team has now confirmed that the impact trimmed 32 minutes off the orbit time, shortening it from 11 hours and 55 minutes to 11 hours and 23 minutes.

While this may not seen particularly significant, even the smallest of nudges can drastically alter an asteroid's path due to the great distances they travel.

"This result is one important step toward understanding the full effect of DART's impact with its target asteroid," said Dr Lori Glaze, director of NASA's Planetary Science Division at NASA headquarters in Washington.

"As new data come in each day, astronomers will be able to better assess whether, and how, a mission like DART could be used in the future to help protect Earth from a collision with an asteroid if we ever discover one headed our way."

The team is still acquiring data on the collision and hopes to uncover more details about the impact.

"DART has given us some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defence technology," said Dr Nancy Chabot, the DART coordination lead from the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland.

"The DART team is continuing to work on this rich dataset to fully understand this first planetary defence test of asteroid deflection."

NASA/APL X3, GETTY IMAGES

HEALTH

EATING A BALANCED DIET AND AVOIDING THE NEWS HELPED US THROUGH COVID

The protective effect was even stronger than interacting with friends or enjoying hobbies, a Spanish study has found

A healthy diet and staying away from the news may have been the best way to avoid succumbing to anxiety and depression during the pandemic, a study carried out by researchers in Barcelona has found.

Throughout the course of the COVID-19 pandemic, many of us experienced increased feelings of anxiety and depression. According to the Office of National Statistics, around one in five adults in the UK experienced some form of depression at the height of the pandemic. This compares to around one in 10 before the pandemic.

To make the discovery, the researchers asked almost 1,000 adult Spanish volunteers to note their levels of anxiety and depression, along with the coping behaviours they carried out, for one year during the COVID pandemic. When presenting their findings at the 35th European College of Neuropsychopharmacology annual conference in Vienna, the team reported that following a healthy, balanced diet and not reading too many news updates about COVID were most associated with coping better with the pandemic. Taking regular exercise, going outdoors and relaxing were also seen to have a benefit.

However, some behaviours that were widely recommended to be beneficial, such as talking with relatives or friends, or spending time on a hobby, had a much smaller effect.

"This was a little surprising. Like many people, we had assumed that personal contact would play a bigger part in avoiding anxiety and depression during stressful times," said lead researcher Dr Joaquim Radua, of the Institut d'investigacions Biomèdiques August Pi i Sunyer, Barcelona.

"The relationships between behaviours and symptoms were difficult to tease out because we were looking at what happens over time, rather than just at a single moment of analysis," he added.

Though the study is yet to be fully peer-reviewed, it could provide a valuable insight into how we can better cope with stressful situations.

"Our work was centred on COVID, but we now need to see if these factors apply to other stressful circumstances," said Radua. "These simple behaviours may prevent anxiety and depression, and prevention is better than cure."

Following a healthy diet may have helped people stave off anxiety and depression during the COVID pandemic

PALAEONTOLOGY

ANCIENT CAT-SIZED REPTILE REBUILT IN EXQUISITE DETAIL

Fossils unearthed in Scotland more than 100 years ago have finally been identified as belonging to relatives of the flying reptiles that ruled the skies in the age of the dinosaurs

Researchers based at National Museums Scotland have identified the early pterosaur ancestor *Scleromochlus taylori* by making casts of impressions left in sandstone by several specimens of the reptile found in northeast Scotland.

They then CT scanned these impressions and recreated the skeletons of the animals using 3D-modelling software.

This enabled them to piece together the fine details of their anatomy and placed them in the family tree of lagerpetids, the closest relatives to pterosaurs.

Scleromochlus was a small, cat-sized animal that lived in what is now Elgin in northeast Scotland, around 235 million years ago.

Although the fossils were first found in the early 20th Century, classifying *Scleromochlus* proved problematic due to the difficulty in correctly identifying the fine detail in its anatomy.

"It's exciting to be able to resolve a debate that's been going on for over a century," said lead researcher Dr Davide Foffa, a former research associate at National Museums Scotland.

"But it is far more amazing to be able to see and understand an animal which lived 230 million years ago, and its relationship with the first animals ever to have flown."

1

2

PAUL BARRETT, GABRIEL UGUETO, NORTHERN ROGUE STUDIOS X2

1. One of the sandstone samples used in the study, with the imprint of *Scleromochlus* visible in the centre of the stone

2. *Scleromochlus* was around 20cm from nose to tail, with long, graceful limbs

3. CT scan data of the fossils was used by Matt Humpage of Northern Rogue Studios to create finely detailed 3D models of *Scleromochlus's* skeleton

3

HORIZONS

BIOLOGY

GENE-EDITED SHEEP OFFER A GLIMMER OF HOPE IN DEVELOPING A TREATMENT FOR A FORM OF CHILDHOOD DEMENTIA

Scientists at Edinburgh's Roslin Institute have created sheep that carry the gene for Batten disease, a rare and fatal childhood illness for which there is currently no cure. **Dr Thomas Wishart** tells us more

WHAT IS BATTEN DISEASE?

Batten disease is a term for a group of diseases which are also known as neuronal ceroid lipofuscinoses, or lysosomal storage disorders. These are conditions where patients carry mutations or faults in genes that ultimately end up affecting the function of the lysosomes, which are the cells' waste disposal and recycling system. Lysosomal storage disorders are generally referred to as the most common form of dementia in childhood.

There are 14 different forms of the disease that we're aware of. They are what we call neurodegenerative diseases and affect the function of the nervous system. It's a rare disease. In the UK, there are maybe 100 or 150 patients at the moment. But obviously that doesn't make it any less impactful for those people who have it and their carers.

DOES THE DISEASE AFFECT CHILDREN FROM BIRTH?

Not necessarily. As I said, there are 14 different forms and they all affect the function of the lysosomes, this waste disposal and recycling system in the cell.

The majority of the presentations are similar, with the main difference being the time of onset – the age at which they start to get sick – and how long that goes on for before they die prematurely.

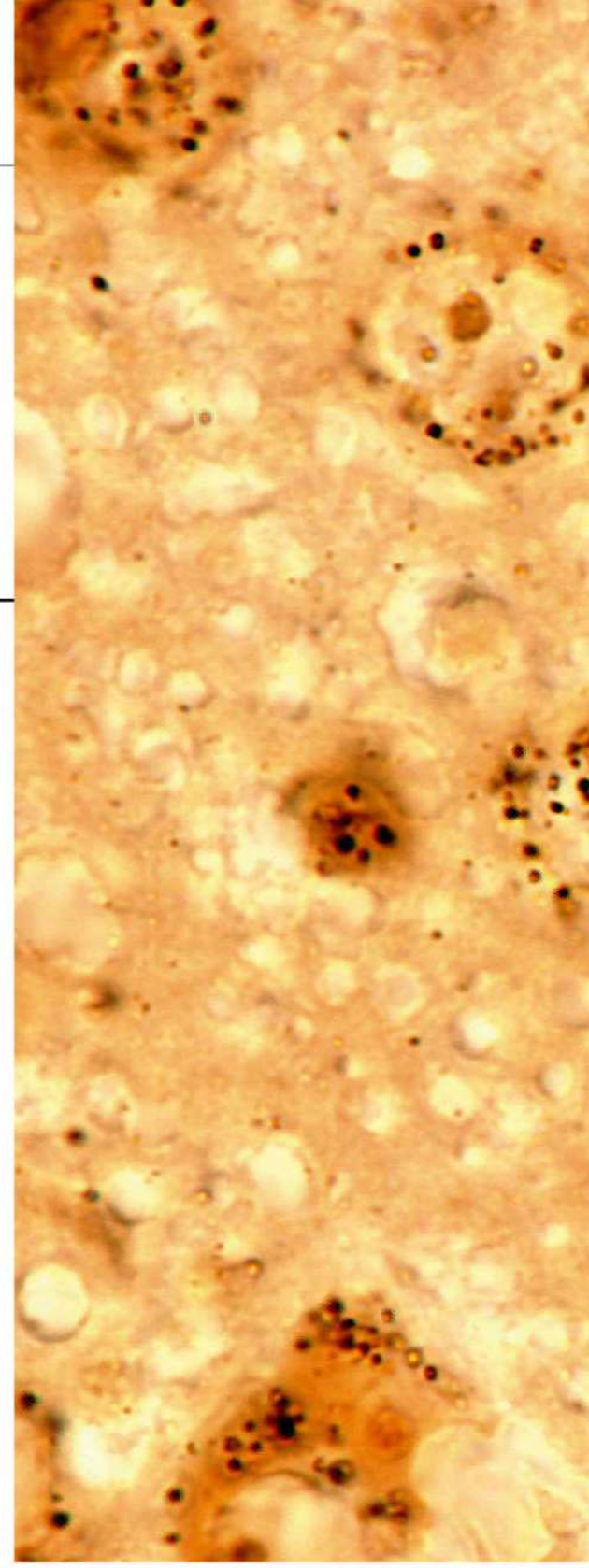
The form of the disease that we are talking about, which is called the CLN1 form of the disease, is quite early onset. Typically, the first presentation of disease is that the kids, unfortunately, go blind. Then they'll have more core cognitive deficits, such as changes in their thought processes, or their ability to retain information or develop new memories, and their ability to interact with family members.

They develop motor changes, which means that their ability to move around and coordinate their abilities is affected. And normally they'll end up in a wheelchair quite rapidly and then lose mobility. Ultimately, most of these children will have passed away by the time they're 10 years old.

SO YOUR WORK IS CENTRED ON THE DISEASE THAT IS CAUSED BY A FAULTY CLN1 GENE?

Yes. Each of the different forms of Batten disease affects a different gene that impacts on lysosome function. For this form of the disease, the gene is called CLN1. It is supposed to produce an enzyme called PPT1, and that plays a role in lysosome function.

YOU THEN GENETICALLY ENGINEERED SHEEP TO CARRY THIS FAULTY GENE AND TREATED THEM WITH THE MISSING ENZYME?



SCIENCE PHOTO LIBRARY

Our collaborators in the United States already have a mouse model for this particular disease. Mice are useful for carrying out some basic biology work, but they are not much like people and that's a big problem at the moment. In general terms, we call it translation – moving something from rodent-derived therapeutics into something which is actually going to be effective in the clinic. We need an intermediate model system, if you like, to be able to show that we can effectively scale up [from small to large].

In the nervous system of a mouse, if you put the enzyme into the fluid-filled spaces in the brain, the ventricles, the maximum distance it has to travel to get complete coverage of the brain is only two or three millimetres in any direction. If you want to do it into the brain of a child, it then has to go two centimetres in every direction. So, just because we can do it in a mouse, it doesn't

Lysosomes (black dots) inside nerve cells

“This is a proof of principle that is worth following up and is likely to be a viable route to developing a therapy”

necessarily mean that it’s going to be effective in a human as well.

To be clear – and I think we try and stress this point – nobody wants to do large animal therapeutic research. But there’s no alternative for showing that you can effectively make that transition from small-scale therapy to something that is actually going to be effective in the clinic.

HOW FAR ALONG IS THE RESEARCH?

Our collaborators in the States have shown that this is a viable route for essentially rescuing the disease in a mouse model. We’ve managed to show that if we scale up the administration of this therapy into sheep, again into the fluid-filled spaces of the brain, and we give this therapy monthly, then we can change the progression of the disease.

WHAT ARE THE NEXT STEPS?

It’s very, very early stages. This is a proof of principle that is worth following up and is likely to be a viable route to developing a therapy. The next steps are to try to get funding to do this on a larger scale and essentially refine the therapy administration protocol, to try to answer questions like, how much enzyme do you need to give? How often do you need to give it? And where exactly should you be putting it in the first instance?

It is worth reiterating that this is far from being a therapy now. This is an effective proof of principle and it’s promising, but it will be a while before anything is going to go into patients.

DR THOMAS WISHART

Thomas is a reader in molecular anatomy at the University of Edinburgh’s Roslin Institute. He studies the mechanisms underpinning neuronal development and degeneration.

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From clean fuels to pain-reducing pillows, here you'll find many reasons to feel hopeful for our future...

MEDICINAL FUNGUS GROWN ON INSECTS
In nature, the *Cordyceps* fungus infects invertebrates, with the fruiting body eventually erupting from the animal's body, killing it in the process. But despite its ghoulish life history, *Cordyceps* is of interest to scientists as it contains the bioactive substance cordycepin, which could be used for antiviral medications and cancer drugs. The problem is, obtaining it in the wild is difficult, and cultivating the fungus in the lab results in poor yields. Now, however, scientists at Chungbuk National University in South Korea have found that by growing the fungus on edible insects such as crickets, silkworm pupae and rhinoceros beetles, the cordycepin content is increased.

YEARS TO GO

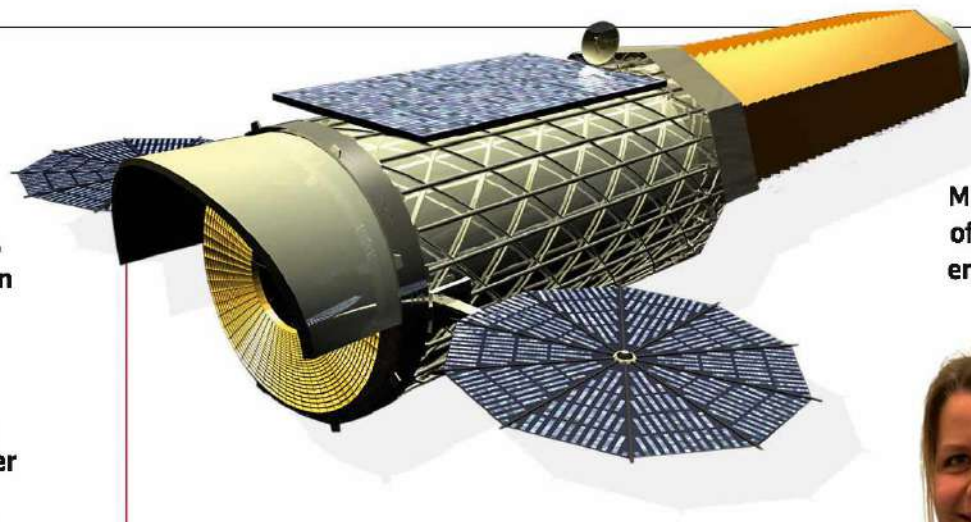
25

POTENTIAL PROTECTION AGAINST ALZHEIMER'S
Scientists at the University of Virginia have found a molecule in the brain that's responsible for regulating the immune system's response to Alzheimer's and other neurodegenerative diseases. The molecule, spleen tyrosine kinase, controls the process of clearing the characteristic brain plaques seen in Alzheimer's, and the brain debris buildup that causes multiple sclerosis. The scientists think it may be possible to supercharge this molecule to enhance the body's 'brain-cleaning' ability.

20

AI COULD ACCELERATE DRUG-APPROVAL PROCESS
CODE-AE, an AI model developed by computer scientists at the City University of New York, is said to be capable of screening new drugs and accurately predicting their efficacy in humans. It could be used to rapidly investigate the early potential of novel medicines, rather than relying on cell or tissue samples, which don't always serve as an accurate proxy for people.

GETTY IMAGES X5, OREGON STATE, NASA/GSFC, LISA ANTONSEN



PAIN-REDUCING PILLOWS
Musical pillows could reduce sensations of pain and anxiety in patients awaiting emergency surgery, according to a small study in Denmark. Listening to music on MP3 players connected to pillows in emergency room beds improved patients' feelings of wellbeing and relaxation as they waited for surgeries to deal with acute conditions including appendicitis, intestinal obstruction, and abscess or inflammation of the gall bladder.

A CLEANER WAY TO GET CLEAN FUEL
Hydrogen gas has potential as a clean alternative to fossil fuel but storing large quantities of it is difficult and dangerous. Now, a new method of converting it into hydrogen salt has been found that makes the fuel easier to handle and transport. Hydrogen salt isn't a new development, but the conversion process currently relies on materials that release CO_2. The new conversion process captures the CO_2 it produces.

JAMES WEBB SPACE TELESCOPE, WATCH OUT!
More revelatory images of deep space could soon be on the way thanks to a new technique for making high-precision, ultra-thin mirrors using brief pulses of laser beams measured in trillionths of a second. Such mirrors can be installed in X-ray telescopes orbiting Earth to capture high-energy cosmic events involved in forming new stars and supermassive black holes. The MIT team behind the technique says it overcomes the problems of the current fabrication method, which can bend and deform the thin material more than is needed.

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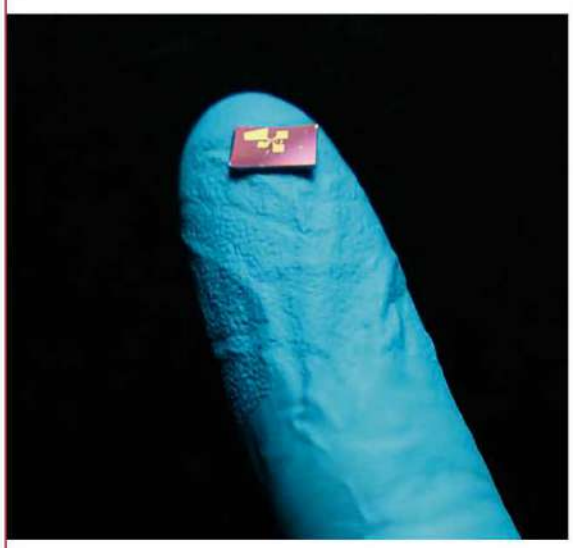


A SPECTROMETER FOR YOUR PHONE
Research led by scientists at Finland's Aalto University has led to the creation of a powerful, ultra-tiny spectrometer that fits on a microchip and is operated using artificial intelligence. Used to measure and analyse light, spectrometers are used in various fields from astronomy to geology, but the devices are typically bulky and expensive. The new, scaled-down spectrometer could be integrated into smartphones, enabling it to do some clever medical tests or even scan the conditions of the environment around it.

0

SAVING THE SEAS SAVES THE PLANET
An analysis of over 22,000 studies and 241 sites has found that marine protected areas not only protect the plants and animals that live within them, but that the benefits spread further afield. The authors of the analysis found that carbon sequestration increased significantly in protected areas where sediment wasn't trawled. They also noted that while the protected areas had greater food security, the fish stocks in adjacent waters also swelled.

COMMENT

BURNOUT MAKES US LESS KIND

Understanding other people's feelings is an essential part of being human. But to look after others, we must first look after ourselves

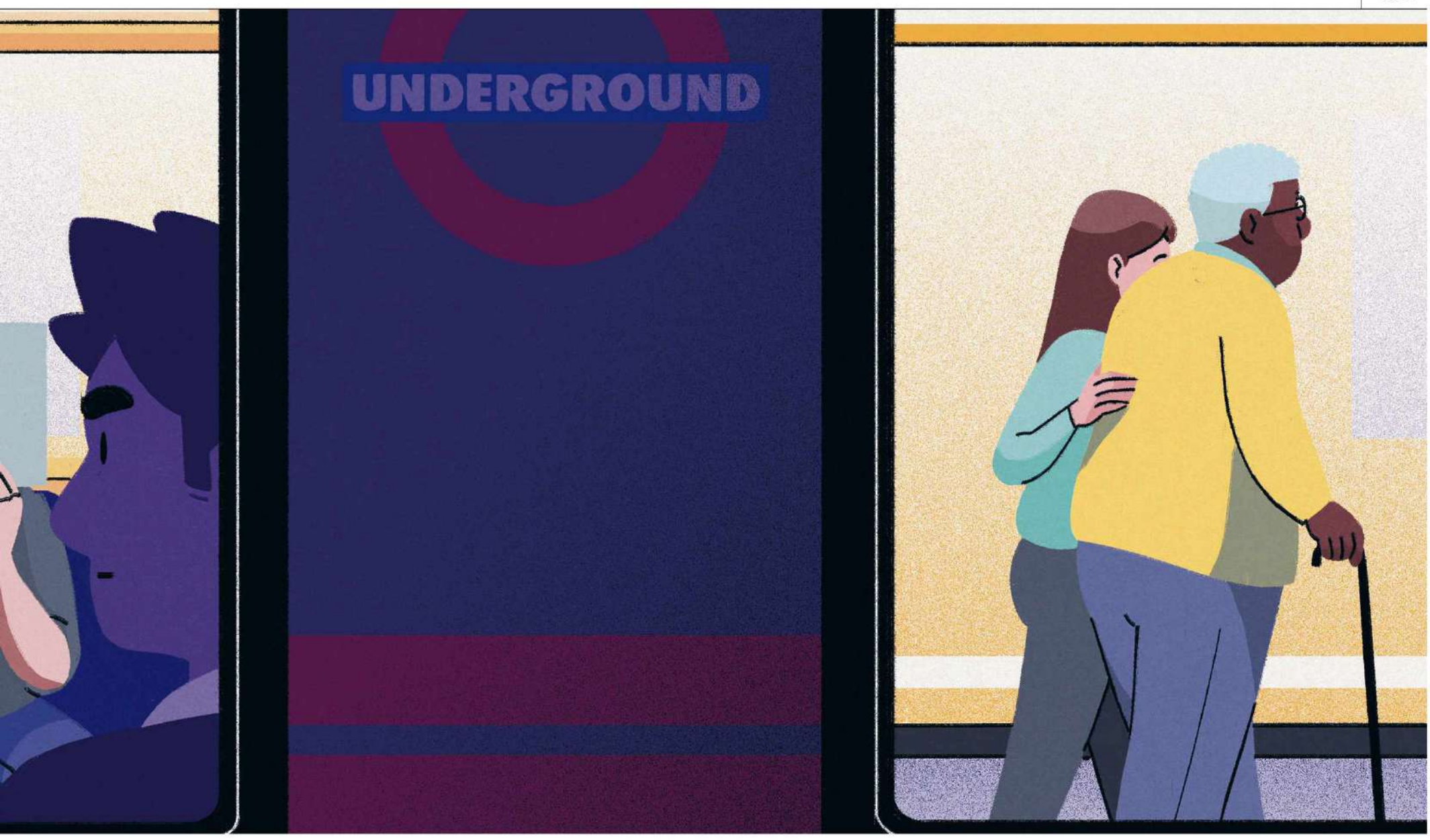
Empathy is a human quality that is absolutely crucial for us all to be able to develop prosocial behaviours and to create and sustain meaningful connections and intimate relationships. You could argue that empathy is the glue that holds society together and communities close.

Empathy can help construct our moral compass and is a barometer of our behaviour to others. Our ability to be empathetic has even been shown to be beneficial for our mental and emotional wellbeing, and contributes towards our ability to handle emotionally challenging situations. So it's clearly vital that we do whatever we can to be at our most empathetic.

And it turns out that getting a good night's sleep is key. A recent study published in the journal *PLOS Biology* has shown that lack of sleep makes us less likely or willing to help others and to demonstrate empathy, thus impacting our social interactions. Researchers from the Neuroscience Institute at the University of California, Berkeley, placed volunteers into an fMRI scanner – once after they'd had eight hours of sleep, and once after they had missed a night's sleep. They found that key parts of the brain involved in empathy became less active after missing sleep. Namely, those in the so-called 'social cognition network' – an area of the brain comprising the prefrontal cortex, mid and superior temporal sulcus, and temporoparietal junction. This network has previously been shown to be activated when we are considering the mental states, needs and perspectives of others.

It isn't just the quantity of sleep that seems to have an impact, but also the quality. Next, the team had 100 individuals log their sleep quality, including factors such as how many times they woke up during the night, and then tested their willingness to perform certain tasks such as holding open a lift door for a stranger.

ILLUSTRATION: DANIEL CRESPO



“A drop in the quality of someone’s sleep led to a significant decrease in their desire to help other people on the following day”

They found that a drop in the quality of someone’s sleep led to a significant decrease in their desire to help other people on the following day – 78 per cent of the participants tested were less likely to offer a helping hand after missing out on sleep.

The researchers also noted that there is a 10 per cent reduction in giving to charities after the clocks went forward in areas of the USA that follow daylight saving time, compared to areas where the clocks do not go forward. They suggest this could be due to the potential loss of an hour’s sleep when the clocks change. So getting good quality sleep is clearly essential for our ability to be empathetic towards others.

Similarly, a systematic review of 10 studies looked at the relationship between professional burnout in healthcare staff and their ability to be empathetic. Eight out of 10 of the studies showed that those experiencing burnout were less likely to be able to demonstrate empathy.

So if we are not looking after ourselves and our own mental health and emotional reserve, we are not able to look out for other people either. The phrase ‘put on your own oxygen mask first’ seems extremely pertinent to our ability to be empathetic and helpful to others, and also to society as a whole. Perhaps this is not a surprise, considering that society is made up of individuals all bringing their own perceptions, problems and skills to the table.

Just as we mirror other people’s feelings and expressions when we are showing empathy, so our communities are really a reflection of how well we are all looking after ourselves. Best get an early night then.

BBC RADIO 1

Listen to Dr Radha Modgil on *Life Hacks* on BBC Radio 1.

DR RADHA MODGIL

(@DrRadhaModgil)

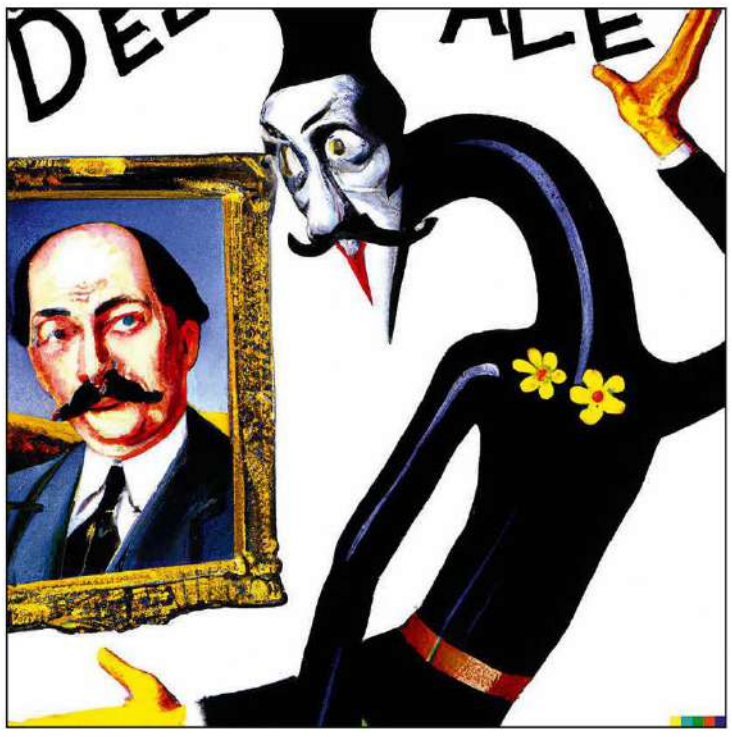
Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1’s Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

COMMENT

WILL AI REPLACE ARTISTS?

AI-generated images and the future of art

For years, artist Steve Coulson wanted to make a comic. "The problem has always been I can't draw," he says. But in 2022, Coulson published a beautiful comic called *Summer Island*. The 40-page, folk-horror story about a sea god festival features detailed illustrations in a coherent visual style. The images were created with the help of artificial intelligence. As AI image generators become more widespread, some forecast the death of human artforms. But AI could make illustration more accessible, allowing for more creators and revitalising visual art.



BELOW We gave the AI image-generation software Dall-E the prompt of "will Dall-E replace Dali?" and this is what it came up

The past year has seen an explosion of machine learning models that generate digital images from natural language prompts. These AI systems use a method called 'diffusion', which creates random dots and then shapes them into a picture according to the semantic information it receives. Type in a description like "the royal skateboard of England on display among the Crown Jewels at the Tower of London" and the AI system will then return multiple images of... approximately that.

The systems aren't perfect, but their accuracy and quality are often breathtaking. They also mean that illustrators and others could automate basic prototyping or even generate a final product for illustration tasks. Which raises the question: will we still value human skill and creativity in visual art? The short answer is yes.

Human creativity is different. Machines imitate, remix and generate art accidentally, not with any human intentionality. Some might quibble and claim that human art is also imitation and remixing, but the process is entirely different. Human creatives are able to be more deliberate or dynamic with their vision, and follow a path of ideas and exploration differently from an AI system. Even if the output is similar, society will continue to value human-created art for these reasons. (As well as other reasons, like our obsession with 'authentic' goods, particularly in the art world.)

Additionally, AI-generated pictures need human direction, input, selection, and sometimes editing. Coulson, in creating his comic, says: "While I tweaked a few things in Photoshop, what you see is basically what you get, if you ask it nicely." That's impressive, but the prompts, selection and the ideas are still arguably the most meaningful piece of the work.

When cameras were invented, pundits declared that photography would be the death of visual art. Decades later, we recognise that photography is art and that the camera is more than an automated picture generator – it's a medium through which people express their creativity.

Illustrators and visual artists will be able to use these AI tools to generate ideas, gather inspiration and experiment with prototypes to edit into a final product. While this won't kill art, it may mean disruption in content creation industries. Hiring an artist won't generate the same volume of images at such speed, so these systems could become a partial or full substitute for illustrators or photographers-for-hire.

Whether for advertising, product design or birthday cards, wherever volume matters more than artistic quality, corporate interest may not care about retaining or retraining human artists, especially if they're mostly contractors. When *Atlantic* journalist Charlie Warzel used an AI-generated image to illustrate a story, he suffered a huge backlash on Twitter from creatives. The fears are justified, and the complaints are unlikely to stem the tide of corporate incentive.

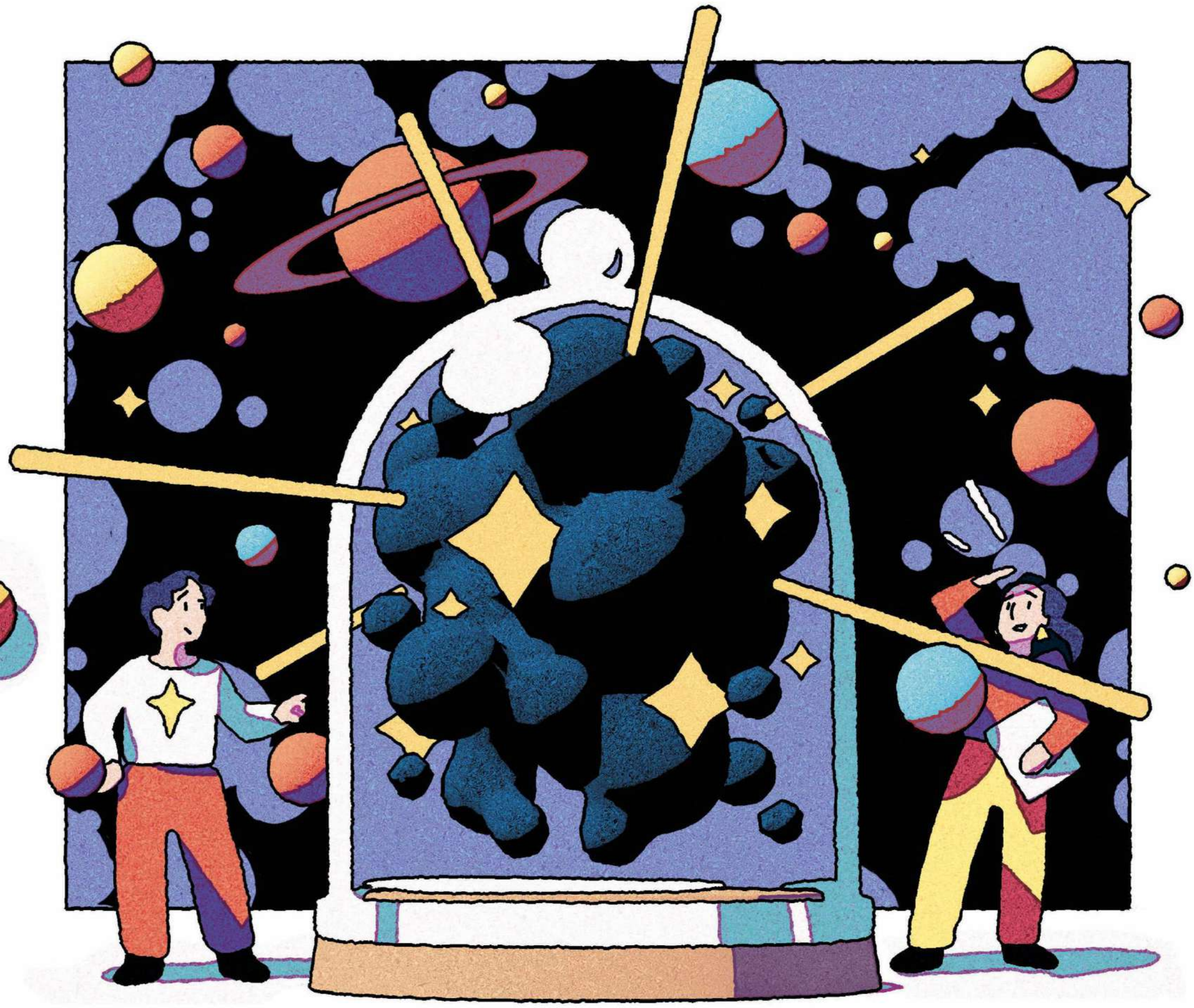
But the ideal societal solution isn't to stop this technology, it's to support people through the labour disruption that it'll cause. When the infamous 19th Century Luddites destroyed industrial machinery, they weren't opposed to technological progress. They were opposed to employers using new technology as an excuse to undermine worker rights – a concern that remains legitimate today. With better political and economic labour support, it would be easier to embrace the disruption brought on by new AI tools, in image generation and elsewhere.

Further disruptions are on the horizon. When Coulson was making his comic, his first draft was an AI-created photo essay in the style of the 1973 movie, *The Wicker Man*. It's likely that AI will be able to create motion pictures in the near future, making it possible for anyone to become a filmmaker by providing the appropriate text prompts. Film as an artform has gone through a lot of changes, from the camcorder, to editing software, to TikTok. This will be the next frontier and it's a big one.

Amid the turmoil these developments bring to creative industries, the exciting part is that the technology is already creating new artists and allowing broader access to illustration. In that sense, machine-generated imagery couldn't be farther from replacing human creativity. Like other media before it, AI may provide more opportunities for people to bring their artistic visions to life.

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

ILLUSTRATION: VALENTIN TKACH



COMMENT

HOW THE FIRST STARS SPLIT THE UNIVERSE APART

Astronomers are delving into the dark period between the light from the Big Bang fading and the birth of the first stars

The light, in the beginning, didn't last.

Everything started out so hot. Pure radiation, at first: drawn from some primeval impulse now lost to the obscurity of over-stretched space-time, hidden behind the wall of fire that seared through every femtometre of an incipient cosmos. There was no source of the light, no ignition point to spread from; it was everything, everywhere, and that everywhere was growing. The cosmos was swelling, space escaping from itself, spreading light across the face of creation until droplets formed: matter was born hot and screaming. The first particles tore through searing plasma in waves,

acoustic vibrations spreading and colliding. The Universe was a sea of ions – unpaired protons and electrons, with a sprinkling of helium and other light nuclei – born nuclear-hot from the all-encompassing furnace. The Universe exhaled fire that slowly turned to atomic ash. Positively charged protons and negative electrons spiralled together to form neutral atoms – the first in the Universe – mostly hydrogen, no longer plasma, not ions, but gas. The gas cooled. It became quiet. The Universe rested for 100 million years.

We call the next phase the Dark Ages. (We astronomers are a literal species.) The light from the Big Bang was fading, stretching out toward the radio spectrum; the first stars had yet to ignite. For eons, the cosmos was filled with a dark hydrogen fog, diffusing with the expansion of the Universe, its residual heat fading.

And yet…

The fog could feel its own weight. When the roiling plasma waves cooled, they left their wave crests behind, imprinted in the gas as tiny imperfections. A few more atoms here; a slightly thinner collection there. The mass of an atom is minuscule, but give it time and it'll find its neighbours. The thickest fog formed clouds; the densest clouds formed knots. The knots grew heavier, pulling gas into orbit around them, spinning and crashing together with such force that the gas was compressed into ignition. The same gas that sat dormant for countless ages was, in the centre of the tightest cloud, converted back into a nuclear furnace blazing with heat. The first star was born: Cosmic Dawn.

Amid the thick haze of the cosmos, stars sparked to life: tiny points of blinding light, shining in the darkness. They clustered together where the largest clumps had gathered: the age of the galaxies had begun. Each galaxy was born into a shallow pool of its own light, shrouded from view by the dark, dense clouds that formed it, like a city light smothered by fog. The vagaries of atomic physics make hydrogen an effective star shield: give a hydrogen atom a photon of visible light and it'll consume it entirely, bumping its electron to a higher energy state, only to burp the light out later in a random direction. But this shield is a self-limiting thing. The light from the first galaxies carried harder radiation too: ultraviolet light, so energetic that an incautious hydrogen atom could have its electron not excited, but zapped away entirely. Bubbles of hydrogen-ripping galaxy light began to grow, carving holes in the cold, quiet bulk of the intergalactic gas. Over a billion years, the bubbles filled the cosmos and nearly every hydrogen atom was torn in two, leaving protons and electrons to wander the Universe separately again – not a fire this time, but a diffuse, dissipating haze of once-again ionised gas.

NERISSA ESCANLAR ILLUSTRATION: KYLE SMART

"As we look across the Universe, to galaxies whose ancient light comes to us from farther back in time, we can begin to see the quenching of that light, as though watching a cosmic film in reverse"

We're still learning the story of how the first stars split the Universe apart. We call it 'reionisation', and our knowledge of it comes primarily from its ending. An ionised cosmos is one that is transparent to visible light; as we look across the Universe, to galaxies whose ancient light comes to us from farther back in time, we can begin to see the quenching of that light, as though watching the cosmic film in reverse – the thick neutral gas spreads out and shrouds the galaxies until they're almost entirely hidden from view.

We're fortunate, though, to have ways to cut through the fog. Visible light may be consumed, but longer wavelengths of radiation – infrared, microwave, and radio – can travel unimpeded, and starlight is full-spectrum. With new telescopes like the James Webb Space Telescope, we can peer into the epoch of reionisation by capturing the infrared part of the galaxies' light. With new radio telescopes we may do even better, tuning in to low frequencies of radio light emitted or absorbed by neutral hydrogen itself.

To understand reionisation is to know the first stars and galaxies. Perhaps someday we'll watch them carve away their own natal shrouds, tiny sparks stretching out across a sea of darkness to change it, fundamentally, forever.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

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REALITY CHECK

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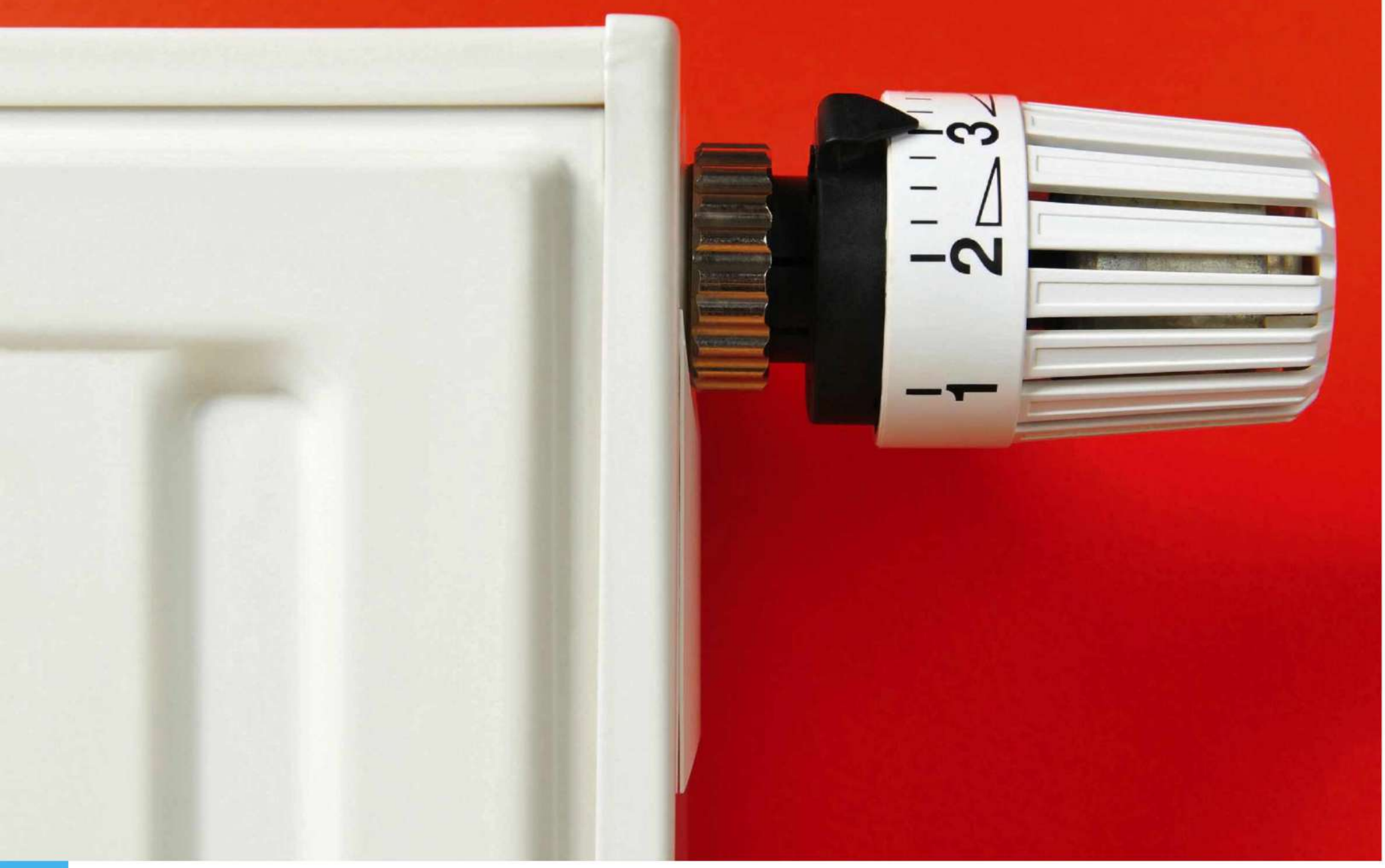
Cost of living | Relationship red flags | Brain implants



REVIEW

COST OF LIVING: COULD COLD HOMES MAKE US ILL?

With household bills rocketing and wages remaining stagnant, many of us are leaving our heating off in an effort to save money. But could this impact our health?

"Numerous pieces of research show that cold homes can increase the symptoms of heart disease and respiratory conditions like asthma"

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Pre-COVID, 50 million homes across the EU were not being properly heated. Now, with economies weakened by the pandemic and energy costs soaring, that number is thought to be much higher. In the UK alone, an estimated seven million households are spending more than 10 per cent of their income on fuel, putting them in 'fuel poverty'. But what does turning down the dial mean for our health?

CAN LIVING IN A COLD HOME MAKE YOU ILL?

Yes, and there are decades of public health studies to prove it. Numerous pieces of research show that cold homes can increase symptoms of heart disease and respiratory conditions like asthma, as well as regular coughs and colds. "We know that cold homes have a very detrimental impact on health and will continue to do so in the winter for a large proportion of the population due to the fuel price increases," says Matthew Scott, senior research and policy officer for the UK charity National Energy Action.

A 2019 study in UK adults linked lower indoor temperatures to higher blood pressure, perhaps partly explaining why more people die from heart disease and stroke in the winter. Meanwhile, the damp and mould that come with cold homes are known to cause respiratory problems and are often associated with wheezing and asthma in children. One 2019 New Zealand study suggested that hospital stays for under-twos with acute respiratory infections could be reduced by 20 per cent just by dealing with household damp and mould.

We know that more people were living in fuel or energy poverty after the global financial crisis in 2007, which made them more vulnerable to the health issues caused by cold homes. So we should be better prepared for what's happening now, says Laura Oliveras, who studies energy poverty at the Pompeu Fabra University in Barcelona. "We're now in another crisis," she says. "So if we don't do something different, we can expect the same result, which is an increase in energy poverty and an increase in the impacts on health."

WHO IS MOST AT RISK?

Being cold doesn't have the same effect on everyone, because we're not all equally vulnerable. People who already have respiratory conditions, such as chronic obstructive pulmonary disease (COPD) and asthma, for instance, may suffer serious breathing difficulties due to the cold because it causes their airways to tighten. The very old and the very young also tend to be more vulnerable to the effects of cold homes, partly because they're not as good at regulating their body temperature. Meanwhile, people with disabilities may find it harder to leave the house, increasing exposure to the cold and damp conditions indoors that lead to poor health.

Even living in a warmer climate won't necessarily protect you. Some of the worst rates of energy poverty and excess winter deaths across Europe are, unexpectedly, found in Mediterranean countries like Spain, according to Oliveras's work. This is because heating systems in these countries are often unable to cope with even mild winter temperatures. People living in Scandinavia, on the other hand, tend to be better protected.

BELOW Cold winter weather can have enormous impacts both outdoors and indoors

GETTY IMAGES X2

WHAT ABOUT MENTAL HEALTH?

Anything that makes us uncomfortable in the place we spend most of our time is bound to have an impact on our mental health – whether it's the neighbour's dog barking or the cold. You may feel stressed, lose sleep or even become depressed. When it's a cold home, the stress may also be linked to concern about rising energy bills. As Oliveras points out, these worries can have an immediate impact. "With physical health effects, you need time to be exposed," she says. "But if you can't pay your bills, you're accumulating debt and concerned about how to use less energy at the same time as you have the discomfort of being cold. All of this has a very fast effect on mental health."

If you're a parent, the mental load will be even greater because you'll also be worried about the impact it has on your children. Parents of children under nine were more likely to be depressed if they lived in cold homes or were unable to pay their energy bills, according to a 2022 study on Irish families. This parental concern is not misplaced, as studies suggest that children living in cold homes are more likely to say they don't feel happy at home, more likely to drink or smoke, and more likely to suffer mental health conditions.

SO SHOULD I JUST TURN UP THE DIAL?

Many of us simply can't afford to. The UK government has announced universal energy discounts on top of existing cold weather payments. But "people are still very worried and they're still turning everything down," according to Scott, who says that more targeted support is needed this winter to prevent the inevitable ill health effects that come with cold homes. The good news is that concerted efforts to tackle cold living conditions can really help. In a 2022 study, people living in East Sussex, UK, who had heating and insulation work done as part of a fuel poverty programme, filled in a health survey. They reported having fewer chest infections and less pain, as well as feeling less anxious and depressed.

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a science writer based in Bristol, UK.

ANALYSIS

RED FLAGS: IS THERE ANY SCIENCE TO SPOTTING A TOXIC RELATIONSHIP?

Social media is awash with videos that point to signs that suggest you might be in a toxic relationship. But is it really that easy to spot a toxic partner?

Let's face it, few – if any – relationships are blissfully perfect. They all take effort and compromise. They go through highs and lows. Many, perhaps most, will end in a breakup, some dramatically, after an infidelity or a massive disagreement, others through a slow drifting apart. But a toxic relationship is different. It's about more than bumpy patches, disagreements or waning

GETTY IMAGES

ABOVE
Controlling behaviour can come in many forms

romance – something is seriously and harmfully wrong. Social media is full of speculation and warnings about the red flags that imply you could be in one of these worrying partnerships, but what does the science have to say?

The 'toxic' label isn't a scientific term, but it's generally used to imply that a partner is exerting some kind of harmful control or abuse – physical, psychological or both – over the other partner, and part of this will usually involve the victim feeling trapped in the relationship. Less often, it's possible that both partners are mutually involved in variations of toxic behaviour toward the other.

Probably the most obvious red flag is that your partner threatens you physically or actually perpetrates physical violence against you (setting aside forms of consensual and safe sexual practice that involve domination, bondage and similar acts). For a sense of what this kind of physical threat feels like, it can be informative to consider the questionnaires used in domestic violence research. For instance, the Women's Experience With Battering Scale includes items such as, 'He makes me feel unsafe, even in my own home' and 'He can scare me without laying a hand on me'. This measure

"A toxic relationship is different. It's about more than bumpy patches, disagreements or waning romance – something is seriously and harmfully wrong"

is aimed at female victims of male abusers, but of course anyone, regardless of their sex or sexuality, can find themselves the target of an abuser.

A more specific form of toxic control relates to sexual coercion – being made to engage in sexual acts when you don't want to, under physical or other kinds of threat and manipulation. Researchers use various scales to measure this kind of behaviour. One example is the Sexual Coercion In Intimate Relationships Scale which includes items such as 'My partner threatened to have sex with another woman if I did not have sex with him' and 'My partner told me that it was my obligation or duty to have sex with him'.

Being physically threatened, physically hurt, and made to have sex against your will – most people know intuitively that these are serious red flags in any relationship. But there is increasing recognition that broader forms of psychological coercion and manipulation can also be abusive and if your partner is doing this to you, it's another red flag. Indeed, the law was changed in England and Wales in 2015 to introduce a new offence of Controlling or Coercive Behaviour that recognises the emotional and mental harm that is caused by psychological manipulation.

Psychological control and coercion can take a vast many forms, such as isolating you from financial or emotional support; restricting your access to friends and family; monitoring your behaviour with spyware or other devices; making you feel worthless (via insults or public shaming, for example); and enforcing rules upon you that make you feel humiliated. If your partner makes you doubt your own judgment, this is also manipulative and sometimes referred to as 'gaslighting'.

Again it can be insightful to look at the ways that researchers measure these kind of things. For instance, scholars at the Autonomous University of

Feel like your partner is pulling your strings? You may feel trapped in a relationship when a partner is controlling you

Madrid recently investigated why teenage victims stayed in physically abusive relationships. They used a measure of psychological coercion (specifically toward staying committed to the relationship) that involved statements such as 'My partner encourages me to believe that life is meaningless outside of the relationship' and 'My partner makes me feel that I should be grateful to him/her to stay in the relationship'.

All the red flags mentioned here are those in the other person's behaviour that indicate you are in a toxic relationship. But another important component is how the relationship is making you feel, both mentally and physically. If the stress of your relationship is severely affecting your sleep; if you feel constantly emotionally drained (such as being made to feel guilty, ashamed or afraid); if you're manifesting physical symptoms as a consequence of the unhappiness and pressure of the relationship (such as tightness in your chest, nausea or constant headaches); and/or if you find yourself regularly dreading seeing your partner – all these are signs that your relationship has turned toxic and it would be a good idea to consider getting out.

If you feel unable or afraid to speak to your partner about ending a toxic relationship, don't suffer in silence. There are various forms of support available, be that reaching out to a friend or relative in the first instance, speaking to your GP, or contacting a dedicated support service, such as local safe-guarding services or shelters for abuse victims.

by **DR CHRISTIAN JARRETT**

Christian is a psychology and neuroscience writer. His latest book is Be Who You Want: Unlocking The Science Of Personality Change *(£14.99, Robinson).*

COMMENT

MIND-CONTROLLED TECH: IS IT POSSIBLE?

Thought-controlled devices seem exciting and sci-fi, but it does mean having a chip in your head

Some people worry that there's too much technology in our lives. And they may have a point, given how countless people now carry the internet around in their pocket and use it as a primary form of communication. But even if you avoid smartphone use, it's still practically impossible to shun technology in our world. There are computer chips in our watches, our cars, our light switches, even our pets! Where will it end?

Well, if certain people have their way, it'll go even further. We'll have microchips implanted into our brains that can interact with the computers around us by thought alone. It may sound like something from the more hardcore end of science fiction, but it's very much a possibility. And if Elon Musk's recent claims regarding his Neuralink company prove valid (which is… questionable), it could soon be the reality for a great many people.

Musk is just the latest and most obvious example of someone hoping to make a big breakthrough with computer-controlling chips in the brain. Such technology, in various guises, has been around for quite some time. So, what does the future of brain-computer interfaces via microchips implanted in our cortex actually look like?

In many ways, things look quite promising. Thanks to their ability to send and receive information remotely via computers, microchips and other related devices have long been inserted into brains to record, transmit, stimulate, or even block activity in specific neurological locations.

For example, arrays of electrodes have been implanted in the brains of epilepsy patients to better record and even predict the atypical neurological activity that leads to seizures. Similarly, deep-brain stimulation, via implanted devices that induce activity in key brain regions, is an established treatment for things like Parkinson's disease, and is even being looked into for disorders like depression.

Then there are the people who end up with some form of paralysis after an experience that leaves them with nerve damage. Their nerves are no longer capable of relaying signals from their (typically intact and fully functional) brains to their muscles and limbs. Brain implants can increasingly provide a technical workaround, meaning chips can detect

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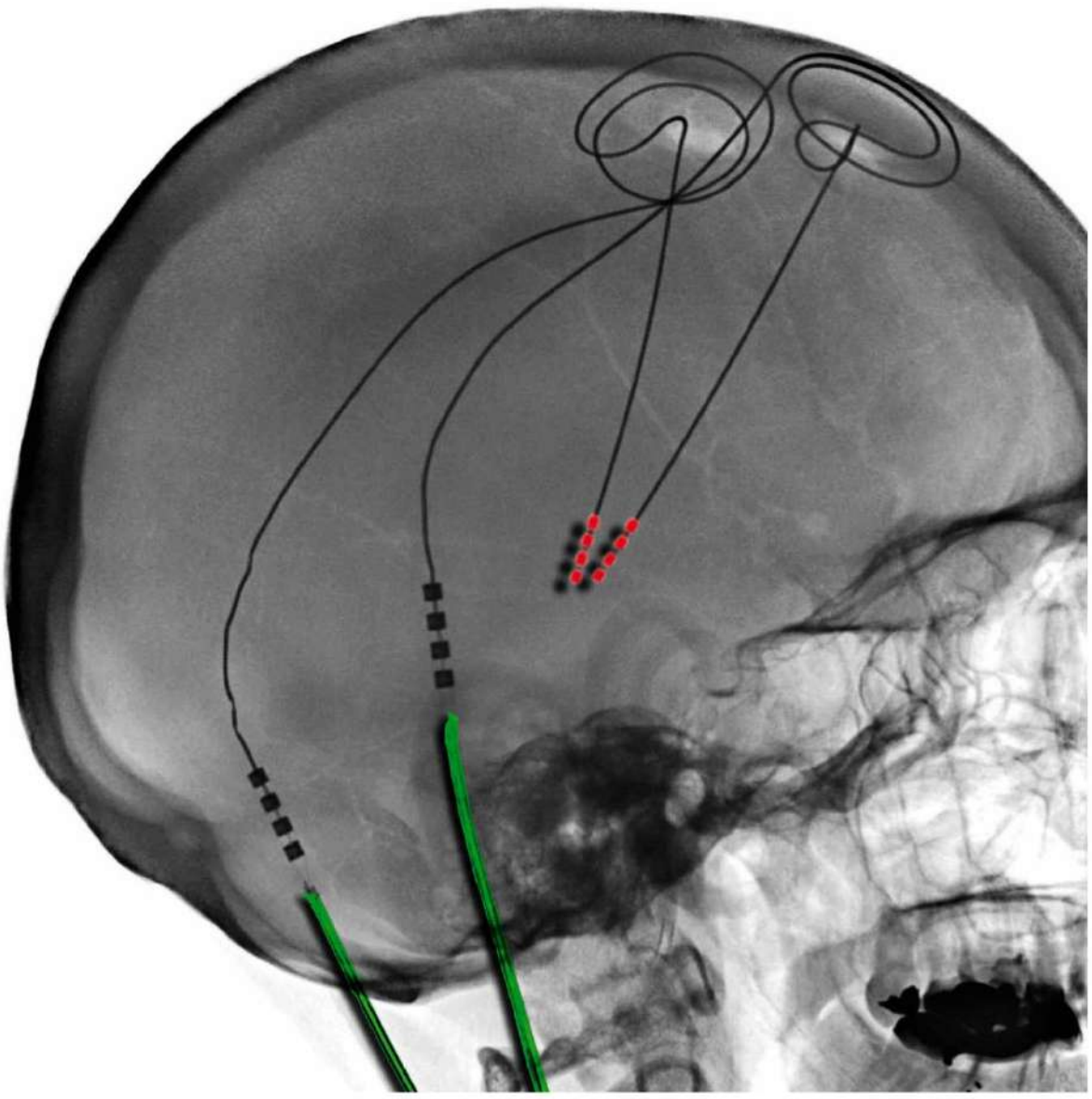
"The prospect of having strangers drill into your skull and stick chips in your brain is likely to prove unpalatable"



and transmit the necessary signals to re-establish a sense of touch, allow complex arm movements, or convey thoughts to a computer, allowing a form of conscious communication. Such interventions have only become more impressive and elaborate as technology and processing power has advanced.

Still, it's one thing to do this for people who can't use their own limbs or communicate voluntarily; in those cases, it's worth the time and effort, as it's genuinely helping them recover some degree of autonomy, or quality of life. But it's very different to installing such devices in healthy individuals.

There are, undeniably, many hurdles that need to be cleared before brain-computer interfaces become an everyday reality. One is that every brain is technically unique, having developed in its own way via the individual's life experiences. So, the particular patterns of activity in one brain that represent even basic things like up and down, or specific words, need not be the same in another. And you'd need to know exactly what the activity in the brain means before you implant chips that read and react to it.

ABOVE Brain implants are already in use to investigate conditions like epilepsy and treat Parkinson's disease

And that's before we get to figuring out the more complex instructions for things like driving cars or playing video games. Translating brain activity for such things into machine-readable information is a big ask.

Then there are the practical concerns, not least of which is what these chips will be made of. The inside of the brain is a mass of highly reactive chemicals and electrical activity. Implants would need to be inert enough to not upset the delicate processes by their presence, but also sensitive enough to read and process the activity around them. Current technology has made impressive progress with this, but if it were to be rolled out to millions of people, we'd need to be 100 per cent certain that it's safe and durable.

But the question that really needs answering is, how many people will actually want to have technology literally inserted into their cortex? A surprising 60 per cent of Americans say they'd be okay with it, but that's when it's purely hypothetical. In reality, the prospect of having strangers drill into your skull and stick chips in your brain is likely to prove unpalatable, especially for a population where millions get furious at fictional microchips in vaccines, and even more are terrified of dentists.

Again, technology exists to solve this dilemma too: some complex brain implants can now be inserted via blood vessels, removing the need to drill into someone's skull. But the options here are limited.

Ultimately, the technology behind computer-brain interface implants is more advanced and impressive than most people realise. But we're still a long way from the point where it's more practical and convenient than just using your hands. **SF**

by **DR DEAN BURNETT** *(@garwboy)*
Dean is a neuroscientist and author. His next book, Emotional Ignorance: Lost And Found In The Science Of Emotion, *is released in January 2023.*

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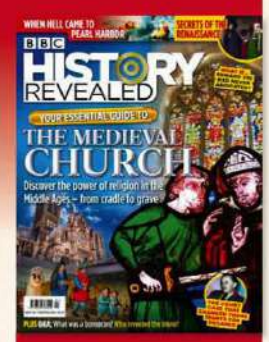

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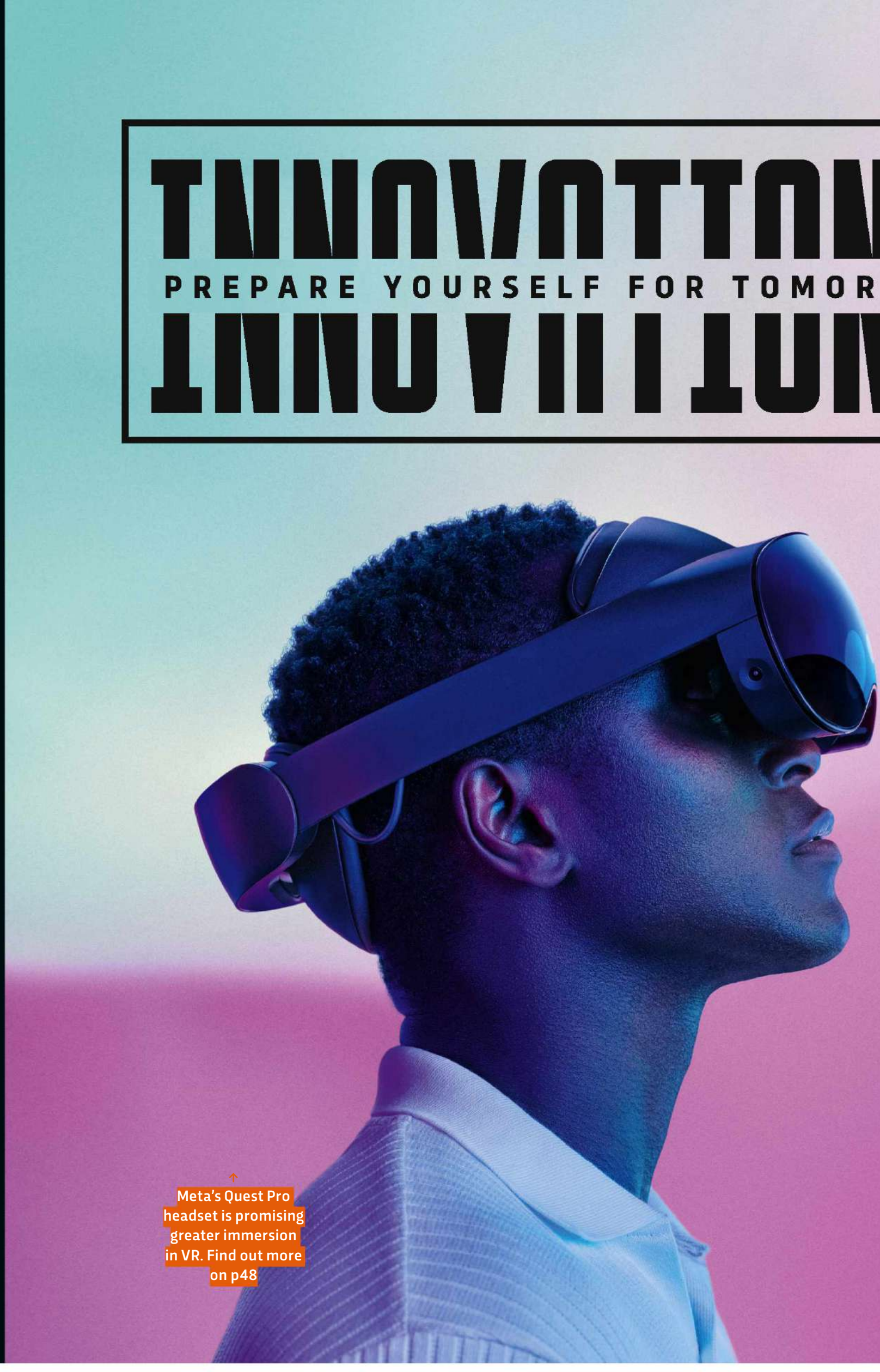


Meta's Quest Pro headset is promising greater immersion in VR. Find out more on p48

ANALYSIS

DRIVERLESS CARS

Coming to the UK's roads in 2025? **p44**

ON TEST

AIRPODS PRO

We try Apple's new earbuds **p46**

NEW TECH

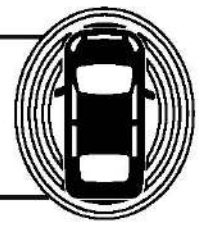
IDEAS WE LIKE

The gadgets we're lusting after **p48**

The percentage of small companies that anticipate having a completely autonomous fleet of cars within 20 years (Gerberin Law)

$54bn

The current value of the global autonomous vehicle market (Vox)



75%

The percentage of people who would rather drive a car than ride in an autonomous one (Advocates For Highway And Auto Safety)

ANALYSIS

Will self-driving cars take over the roads by 2025? It's unlikely

The UK government plans to have self-driving cars on the nation's roads by 2025. We talk to Jack Stilgoe, a leading researcher, who doesn't think much will change

Self-driving cars have rapidly gone from science-fiction trope to the technology of today, with manufacturers all over the world racing to develop the ultimate driverless experience.

While the technology has seen drastic improvements in recent years, we're still a long way from a world free of vehicles that need humans at the wheel. And yet, the UK government has said it wants to get self-driving cars on the road within the next three years. But how realistic is this deadline? And, assuming we hit it, is it going to drastically change the UK's roads? We spoke to Jack Stilgoe, a professor of science and technology policy at University College London, to map out the future of cars.

HITTING THE ROAD

As part of a new plan for self-driving vehicles, the government has committed to spending £100m on supporting innovation in the industry. It estimates the investment will lead to 38,000 new jobs and a complete overhaul of how our roads will look.

While this could mean integration of driverless cars very shortly, Stilgoe

suspects this will be on an incredibly small and limited scale.

"When we say 'self-driving cars by 2025', we need to ask, in what conditions? On what sorts of roads and for which people? The cars are likely to be constrained to motorways, which are already a tidy and safe driving environment," he says. "We might see a self-driving vehicle being able to cope with a motorway scenario in quite a predictable way by 2025."

This is a long way away from self-driving cars being a big part of our infrastructure, however. And that's not really surprising, as the cost of the vehicles will mean they're likely to only be an option for people with high incomes.

REWRITING THE RULES

Despite what these plans for rapid advancements suggest, the UK has fallen behind in terms of self-driving innovation.

"British policymakers say this is an area where Britain can lead, even though we lost all our manufacturing capacity for Ford motor cars a few decades ago and have not been quite so bullish as the US and, increasingly, China – both of which are rapidly accelerating the deployment of [driverless] vehicles in cities," says Stilgoe.

This doesn't mean the UK can't be a key figure in the future of driverless cars, however. "Britain can still play a really important role, which historically it has done with new technologies through the process of standard setting – by helping to write the rules that shape the responsible development of the technology."

"THE CARS ARE LIKELY TO BE CONSTRAINED TO MOTORWAYS, WHICH ARE ALREADY A TIDY AND SAFE DRIVING ENVIRONMENT"

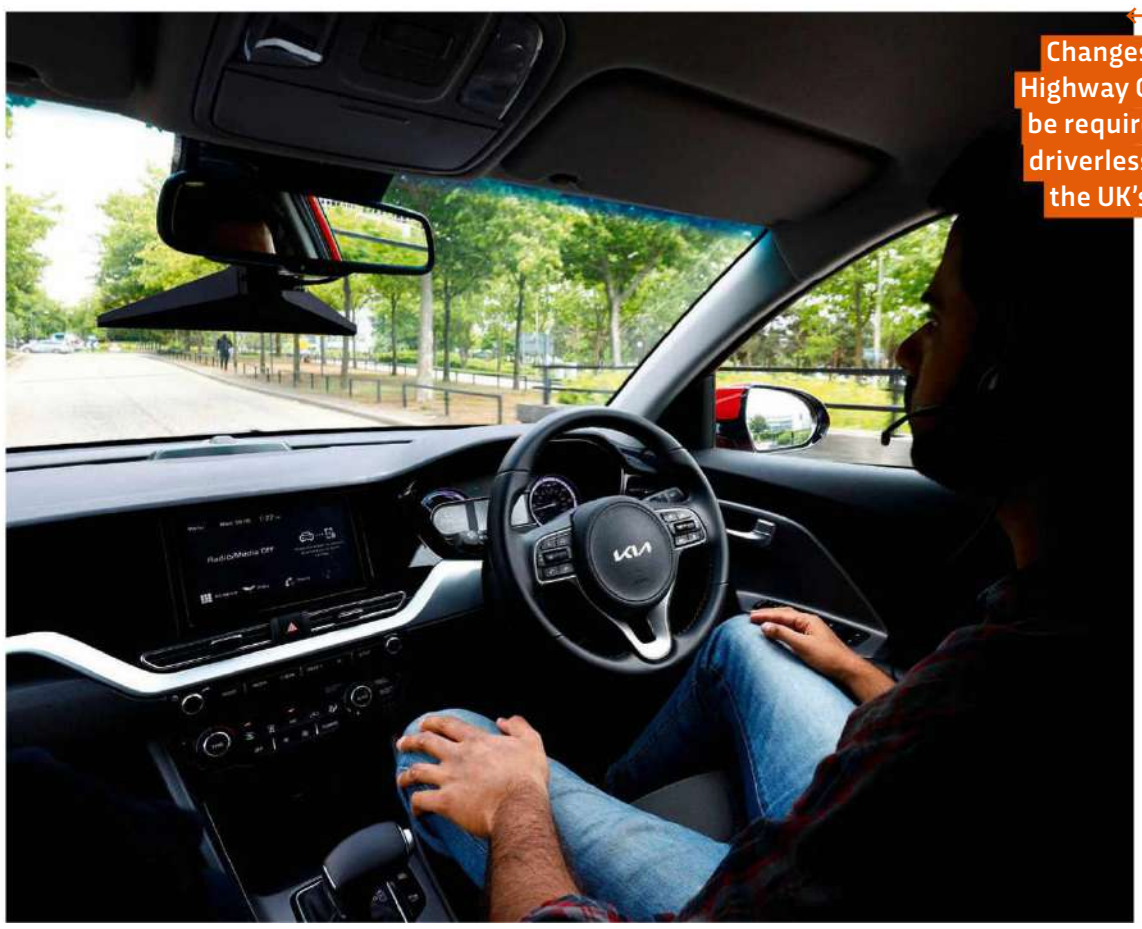
This idea of setting standards and rules is as important as the technology itself. The ethics and legality of self-driving cars have been debated ever since they became a realistic possibility.

"The UK government has been working with the legal profession, thinking through questions of engineering and ethics," says Stilgoe. "The most important task, legally, is to lay out liability and responsibility. [To figure out] who is in control of a vehicle: is a driver liable or is it the manufacturer?"

There are also more subtle, unenforced rules of the road to consider, however.

"The rules we're taught at school [the Green Cross Code, for example] and the Highway Code, which changed recently – these things will need to be taken into account. A self-driving vehicle won't interact with other road users in the same way a human would. But if we change the rules to suit self-driving cars, it could deprioritise other groups of people."

As 2025 approaches, the government and the car manufacturers will need to decide on whether, and how much, the rules of the road need to change to accommodate self-driving cars. Doing so will mean ironing out details such as whether driverless cars should be clearly labelled as such, or if it's okay for them to look like every other vehicle on the road.



Changes to the Highway Code may be required to get driverless cars on the UK's roads

GETTY IMAGES, ALAMY

THE FUTURE OF SELF-DRIVING CARS

Jump forward in time, and what will the future of self-driving cars look like? In the next five years or so, probably not all that different. Innovation for self-driving cars is likely to really take off in places like San Francisco, but for wider expansion, we've got a long way to go.

"We might see a slow rollout of the technology in which the beneficiaries of it are actually rather small," says Stilgoe. "They might be people in rich cities who already have access to a lot of ways of getting around anyway. They might be rich consumers of cars for whom this is just another gimmick."

Currently, there is no real reason to see mass adoption of the technology, especially considering it will take a long time for the cost of buying one to become widely affordable. Stilgoe likens the situation to that of the motorcar in the early 20th Century. While it was eventually adopted by the masses, it was first taken up by a small group. It required the rules of the road to change, and cities and towns to completely change their layouts.

This isn't to say that we won't see a sudden shift, though. "The insurance industry could get involved and say this technology is safer, so we'll make it cheaper for you to use a self-driving car than to drive your own vehicle. The insurance premiums on human drivers going up is likely to change the overall viewpoint very quickly."

Nevertheless, Stilgoe thinks that whatever the eventual outcome turns out to be, it will be arrived at via a "boring but profound" route. Instead of a focus on driverless cars, the biggest developments could be seen in driverless public transport.

In London, there are driverless light rail and Tube trains. Instead of looking to implement autonomous technology on chaotic roads, the existing technology could be developed to boost what's already operating in more controlled environments.

On test:

AirPods Pro (2nd generation)

Are they worth it, asks Daniel Bennett

AirPods are ubiquitous. At least, it certainly seems that way if you set foot on public transport. Little white baubles dangle out of every commuter's ears. So what's the big deal? Is it just a fashion trend or is it worth following the crowd to enjoy better wireless audio?

We tested Apple's new flagship-model earphones, the 2nd generation AirPods Pro, to find out whether there really is some wisdom to be found in the crowd, and if they really are the best wireless earphones money can buy.

GREAT EXPECTATIONS

I should start by admitting I've got high hopes. My other half owns a set of 3rd generation of AirPods. They rarely leave her ears. I could take it personally, but she reassures me that it's testament to the AirPods' comfort and sound quality. We'll see…

First, here's a runthrough of the significant upgrades you can find in the new AirPods Pro. The case is now said to have more accurate sensors to detect if you leave it behind and a louder speaker that you command to sound an alarm if the mislaid case is within range of your phone. It's louder and therefore more helpful than its predecessor. The case also now has a little bar that you can attach a lanyard to.

The batteries in the earbuds are longer lasting too, with six hours of listening time on a single charge (a 90-minute increase over their predecessor). Return the AirPods to the case and you'll get 30 hours use out of them before you need to recharge the case, which can now be done wired or wirelessly. The recharge is pleasingly fast too – you can get an extra half an hour or so of listening by popping the AirPods in the case for as little as five minutes.

Touch controls are new too. Slide up and down the 'stem' of either earbud to adjust volume or give it a squeeze to pause and play music. Holding the stem flicks between noise cancelling and transparency modes. Touch controls are the status quo on earbuds these days. I have no idea why, it's an impossibly small surface to contend with. Maybe I just have grubby, sausage fingers, but I found it too fiddly to bother using. I can't overstate how much I'd prefer some simple controls – skip, volume, shuffle, etc – on the case itself, but this criticism can be levelled at every pair of wireless earbuds (except the JBL Pro Tour 2 earbuds, see p49). That said, the tiny, touch-sensitive surfaces of the AirPods work well if you really don't want to take your phone out of your pocket and are reliable enough for you to operate the AirPods with them.

RICHER SOUND

The most important, and probably most boring, upgrade is the audio chip powering these AirPods: the H2. The extra processing power it provides is what's behind some of the most significant improvements to the AirPods Pro. First off, there's Spatial Audio. This is essentially Apple's version of surround sound: an attempt to simulate the direction that the 'real-life' audio would be coming from, rather than just broadcasting it straight into your ears.

You set this up by sending Apple some pictures of your ears. Presumably not for Tim Cook's personal consumption, but to measure where your ears sit on your head. There's also a short hearing test to check how your AirPods fit and to customise the levels appropriately.

I can't tell you, realistically, whether the test works, but Spatial Audio sounds surprisingly good, particularly

Touch controls, noise cancellation, surround sound and more, all packed into the new AirPods Pro

when it comes to TV and movies. It has the effect of opening up what you're listening to, so that distance and direction are more readily perceivable. In the opening scenes of *Andor*, for instance, you can hear the thrum of a nightclub off at the end of an alley, while the strange planet's denizens call you from behind. It bestows a level of immersion on these earbuds that you could only really get from a big pair of over-the-ear headphones before.

The same feature is available via Apple Music, signified by the Dolby Atmos logo. You can search for Spatial Audio in the Apple Music app, but the selection, though broad, feels limited. That said, when you do find an album suited to spatial audio, like The Weeknd's *After Hours*, it feels like the music's been let out to play – it occupies the space around you. Backing vocals feel like they interject from the sides, drums beat from further back. It empowers the music to help you visualise what you're listening to – play *The Son Of Flynn* from the *TRON: Legacy* soundtrack and you're away in another world.

Even without Spatial Audio baked into a track, my music sounds big and bassy with tonnes of fine detail and no distortion. On a subpar pair of earphones, a track like *Sma3* by Moroccan post-punk band Taqbir, would sound like everything's been thrown into a washing machine. On the AirPods, the thrashing, thumping guitars fight for attention against the punchy female vocals. It's full of aggression with no loss of clarity. If post-punk's not your thing, the gospel melodies of *Gabriels'* backing singers feel full-bodied and powerful, while the lead singer's delicate vocals remain rich and full of details. It's these clashes and contrasts that make the very best earphones stand out from the crowd, and the AirPods perform brilliantly in this respect. Are they the best-sounding earphones out there? I'm not sure. They are on a par with the Sony WF-1000MX4, even if, at times, the AirPods can sound a little clinical – accurate, but missing some magic.

Apple says the active noise cancelling in the AirPods Pro is twice as powerful as its predecessor. While I can't imagine what twice the silence sounds like, the noise cancellation works – almost too well. It takes out most of the low-frequency noise and thrum of a Tube carriage. On the streets, it's a little eerie, which means the transparency mode, which pipes in a little of the outside world, is definitely a welcome feature. It's that H2 processor again, managing the signals from the outside world and figuring out what to do with them.

Oh, and did I mention they're comfortable? They feel barely there. You think they'll drop out half the time, but they never do. It's got to be down to how weight is distributed across the earphone.

AirPods Pro (2nd generation)
From £249, apple.com

VERDICT

The 2nd generation AirPods Pro have the most features we've ever seen on a pair of earphones. There are probably some we've left out. For example, being able to effortlessly switch sources, from your phone to your laptop, is a joy. Sadly, these features will be lost to anyone not embedded in the Apple ecosystem. But this isn't the end of the world, as for Android users the Sony WF-1000MX4 earphones are a worthy alternative, and some ears might prefer their warmer sound quality. But for anyone on an Apple device, the 2nd generation AirPods Pro are hard to look past, and a worthy upgrade over the standard AirPods thanks to their top-of-the-class noise cancellation.

SOUND	4
DESIGN	4
COMFORT	5
FEATURES	5
OVERALL	5

Ideas we like...

Our pick of the month's smartest tech

Meta's new headset aims to improve your ability to interact with VR environments

...a step forward for virtual reality

Oh look… another VR headset. While it would be easy to brush this off as yet another company trying to make VR usable, this one comes from Meta, the company that used to be Facebook before it spent billions rebranding itself as the leading light of virtual universes. The pricey £1,499 headset is thinner than the Meta Quest 2 headset and comes with smarter controllers.

In terms of visuals, processing power and the overall spec sheet, this is the most powerful VR headset yet. Maybe this can finally resolve the trainwreck that is the Metaverse…

Meta Quest Pro
£1,499, meta.com

...a tech-heavy sleep mask

Therabody has released the SmartGoggles in the hope of breaking into the booming sleep tech industry. Essentially, it's an eye mask, but the £174 price tag gets you more than just something to block out light. It uses customised patterns of heat and vibration to lower your heart rate, reduce headaches and give gentle massages to help you sleep more comfortably… provided you can ignore the giant headset strapped to your face.

Therabody SmartGoggles
£174, therabody.com

...a remote control for earbuds

It's always nice to see a tech company try something new – even if it doesn't always work. JBL's new earphones take a unique approach to their controls by incorporating a touchscreen into the charging case. It can be used to change songs, send messages, answer calls and check the time. It's by no means a revolutionary feature, but it is one that prioritises function over style – a big move to make in the world of tech.

JBL Pro Tour 2 Earbuds
$250 (£TBC), jbl.com

...a truly immersive gaming chair

The 'ultimate immersive entertainment experience'. That's how Cooler Master describes its new gaming chair. Hyperbole aside, the chair creates haptic feedback by using sound waves to translate the audio of a game or movie into vibrations. The recoil of a gunshot, the cheers of a crowd in an intense game on *FIFA*, or even the gentle rumble of a tractor in *Farming Simulator* – we won't judge your gaming choices here.

Synk X Haptic chair
£TBC, coolermaster.com

...a smartwatch for adventurers

In typical Apple style, the new Watch Ultra is over-the-top, stylish and expensive. At £849, this massive device is not for the average person. It's made for adrenaline junkies who need a watch that can be hit repeatedly as they climb mountains, dive off cliffs and perform other insane feats. The battery is huge and it can track a whole host of metrics, including your ovulation cycle and blood oxygen levels because… why not?

Apple Watch Ultra
£849, apple.com

IDEAS WE DON'T LIKE...

...SWITCHING OFF AND DOWNGRADING

The Simple Phone does exactly what it says on the tin – it keeps things simple. Instead of an Android OS running apps like Gmail, Photos and Chrome, you get Simple's own 'SimpleOS', which includes the key features like calls and texts, a calendar, clock, camera and music player. In some ways this is a nice idea – removing the distractions of the online world – but it does mean you're paying €399 for what is essentially an outdated smartphone. With a four-year-old processor, dated design, low-resolution display and an unspecified version of Wi-Fi, you'd be much better off just deleting the apps you don't want from your existing smartphone.

Simple Phone
€399 (£340 approx), simplephone.tech

...YET ANOTHER CREEPY ROBOT

We've all seen the videos of robots backflipping, laughing like a human and generally acting as nightmare fuel. But now, there's a new robot to kickstart your fight or flight response. This one's from the mind of Elon Musk: the man making flamethrowers, brain chips and rockets to go to Mars. While Musk sees the Tesla Bot eventually taking over human jobs and implanting into society, based on the first impressions of robotics and AI specialists, the Tesla Bot has a lot of catching up to do before it can even be seen as competitive.

Tesla Bot
$20,000, tesla.com

The Tesla Bot also goes by the name Optimus... wonder what Hasbro has to say about that?

NEXT STOP

IF WE WANT TO EXPLORE THE SOLAR SYSTEM EVEN FURTHER, WE'LL NEED AUTONOMOUS ROBOTS TO HELP US DO IT. AND THAT'S WHY SCIENTISTS ARE PUTTING FUTURISTIC BOTS THROUGH THEIR PACES ON THE LUNAR-LIKE LANDSCAPE OF MOUNT ETNA

WORDS: DR STUART CLARK

Anyone who has followed our efforts to explore other planets over the last few decades will have realised the importance of robots. They're our mechanical eyes and ears on distant worlds, and have allowed us to see places that would have otherwise remained shrouded in mystery. Perhaps this is why the landing of each new NASA rover on Mars draws millions of viewers online.

Recently, however, most of the headlines have been about the imminent return of humans to the Moon. So with people once again venturing further out into space, will robotic explorers start to fade in importance?

Not at all. The fact is robotic explorers are set to become more important than ever. "There are some places in the Solar System you can't send humans, Venus, for example, or some moons of Jupiter or Saturn," says Prof Alin Albu-Schäffer from the Institute of Robotics and Mechatronics at the German Aerospace Center, Munich. "They're just too far away and too hostile for humans. So, you know, robots will be very important."

And it's not just in these remote places that robots will find their purpose. "Before you have humans on Mars, we'll have robots preparing infrastructure," ▶

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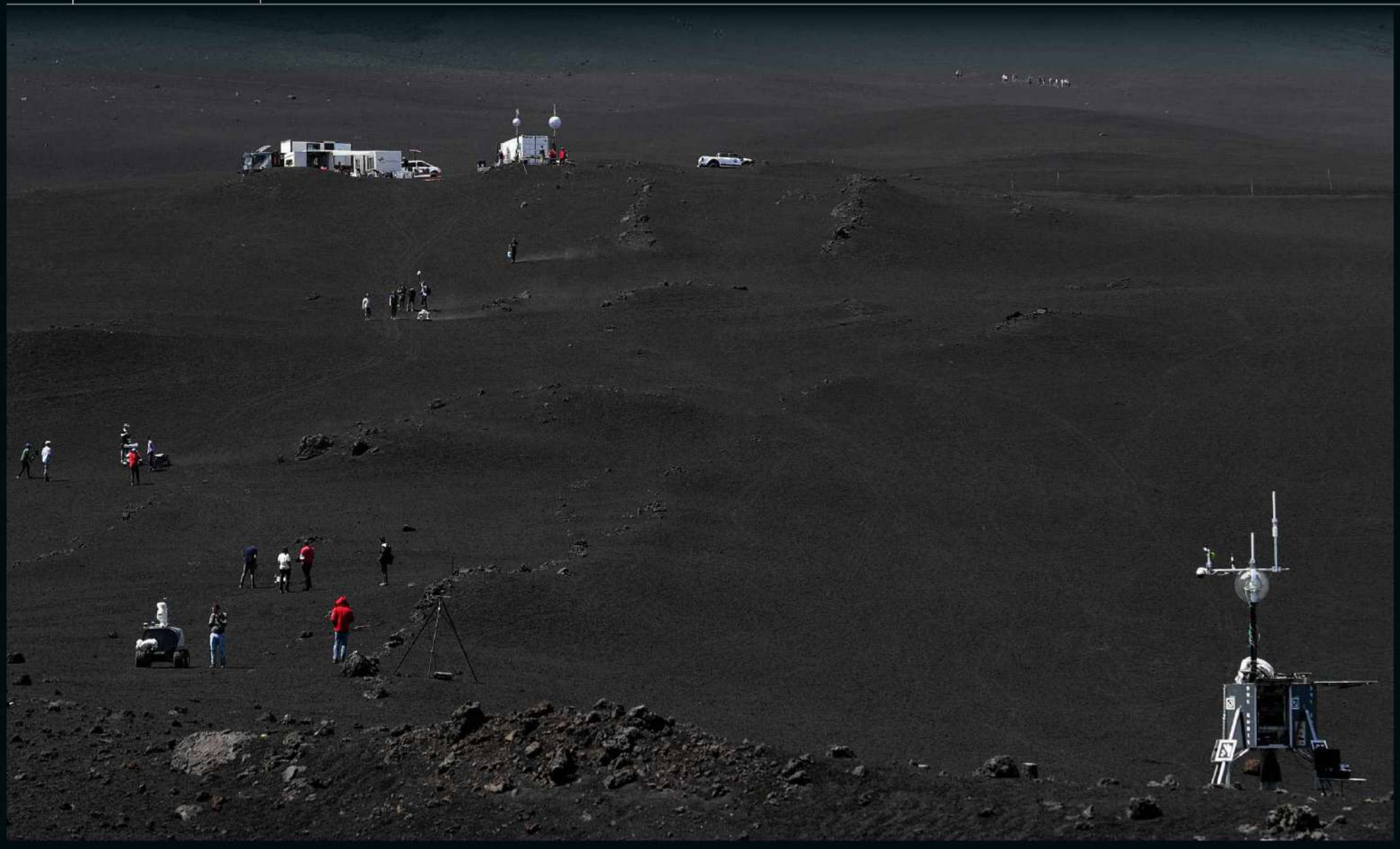
THE MOON



says Albu-Schäffer. The robots will almost certainly help astronauts to construct lunar bases too.

ROBOTS IN SPACE

Albu-Schäffer is part of a German-led project called ARCHES. Short for Autonomous Robotic Networks to Help Modern Societies, ARCHES brings together a team of experts from two of Germany's Helmholtz Research Centres, the German Aerospace Centre (DLR) and the Karlsruhe Institute of Technology (KIT), as well as the European Space Agency (ESA), in order to develop networks of robotic systems that work in collaboration to explore planetary landscapes.

Instead of single envoys that await orders from operators on Earth, tomorrow's planetary robots will work in teams, communicating between each other with their artificial brains, solving problems and achieving goals.

To test such a networked system, Albu-Schäffer and others recently completed an 'analogue mission' on the slopes of Mount Etna, Sicily.

With its desolate landscape of fine, granular surface material and solidified lava flows, the volcano is a good substitute for the Moon. Indeed, it has a history of being used for such tests. A previous Helmholtz expedition took to the slopes in 2017. The Robotic Exploration Under Extreme Conditions (ROBEX) mission tested novel, innovative technologies for energy exchange, data transfer and as much autonomy as possible. It demonstrated that these technologies could be used for future exploration missions, with ARCHES now building on these findings and refining them.

The ARCHES analogue mission took place from 13 June to 9 July 2022. Three different scenarios were undertaken. In the first, called GEO I, two rovers (LRU1 and LRU2) and a flying drone explored an area of terrain using as much onboard automation as possible. The drone mapped the area from the sky, while the rovers wandered around conducting scientific examinations. A central stationary 'lander' supplied power to the rovers and acted as a Wi-Fi station, allowing them to communicate with each other.

"If the rover got stuck because of some bigger rocks, for example, then the flying system would make a map and recognise passages where the rover can pass," says Albu-Schäffer. The drone would then exchange that data with the rover, so that it could replan its route.

A control centre in the nearby city of Catania monitored the robots' progress, but, as far as possible, the rovers made their own artificially intelligent decisions about where to place scientific equipment, take soil samples and conduct other geological investigations.

On Mars or the Moon, such results would be used to decide which areas make the best landing places for human missions. For example, the data could reveal places to find water, or the location of the best materials from which to make building materials or 3D-printed

PREVIOUS PAGE The centipede-like crawler can hack through difficult terrain better than wheeled rovers

ABOVE The central stationary 'lander' sitting in the lava landscape of Mount Etna. The lander carries various tools and containers for the rovers

TOP RIGHT Lightweight Rover Unit 2 (LRU2) picks up a rock sample from the surface and places it in a transport box. LRU2 can use different tools; it collects them from the lander and returns them after use

BOTTOM RIGHT The lander alongside Lightweight Rover Unit 1 (LRU1). LRU1 evaluates samples using its cameras

“THE DRONE MAPPED THE AREA FROM THE SKY, WHILE THE ROVERS WANDERED AROUND CONDUCTING EXAMINATIONS”

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“THIS IS ESSENTIALLY
A ROLEPLAY IN WHICH
THE IN-SCENARIO
PLAYERS EXPERIENCE
COMPLETE IMMERSION”

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LEFT LRU2 trundling across the slopes of Mount Etna

parts. Such construction and resources extraction would significantly reduce the cost of human missions by removing the need to bring all these things from Earth.

MISSION CONTROL

In the second scenario, GEO II, two more rovers joined the DLR network. One was the Interact rover, designed by ESA's Human Robot Interaction Lab. This four-wheel rover is operated remotely and has been designed with a robotic grabber hand. The other was a centipede-like crawler, supplied by KIT. Its novel crawling system of locomotion meant that it could handle much tougher terrain than the wheeled rovers. It also served as a communications relay between the lander and the ESA rover, extending the latter's range.

Over a four-day period, the ESA rover selected rock samples and delivered them to the lander. The Interact rover was controlled remotely by a human operator, the ESA astronaut Thomas Reiter, who was stationed in Catania, around 23km (14 miles) from Mount Etna.

This setup mimicked the idea of having an astronaut on the Gateway station (to be constructed in lunar orbit), operating a rover on the surface of the Moon. To further enhance the simulation and give a sense of there being a mission control on Earth, ESA's European Space Operations Centre in Darmstadt, Germany, monitored and coordinated the rover's operations with Reiter in Sicily.

"A simulated mission like this is essentially a roleplay in which it's very important that the in-scenario players experience complete immersion," says Kjetil Wormnes, ESA's project manager for the analogue mission.

For maximum immersion, the team even set up a one-second time delay in the signal from Reiter to the rover, the same delay they expect to see between Gateway and the lunar surface.

The attention to detail was worth it. "It was a challenging setup, but the systems worked extremely well and we learned a lot about operating a rover on the Moon that can help us when we do this for real in the future," says Wormnes.

The final scenario was called LOFAR and involved the rovers working together to place four low-frequency radio receivers in the optimal positions to create an array. The receivers weren't dummies but working models. After deployment of the receivers, the astronomers in Catania used them to monitor Jupiter. They even picked up a radio burst as the moon Io passed through the planet's magnetic field.

It has long been a dream of astronomers to construct a large radio telescope on the far side of the Moon, where it'll be shadowed from the noise of terrestrial radio stations. But to do this in a place where there's no direct contact with Earth will require automatous robots and astronauts in the lunar orbit to oversee the construction.

"IT HAS LONG BEEN A DREAM OF ASTRONOMERS TO CONSTRUCT A LARGE RADIO TELESCOPE ON THE FAR SIDE OF THE MOON"

All in all, 50 people were involved in trials from the different institutions. As a result, team building became another aspect of the success. "There was a lot of community building because we had these people working together and building the building blocks for such space missions. So I think having this campaign with the researchers for four weeks up there on the mountain was priceless," says Albu-Schäffer.

The advances made by the ARCHES project extend beyond space exploration. They can also help in the robotic exploration of deep-sea environments on Earth, and in places where it would be too dangerous for humans to work, for example, dismantling nuclear power plants or inspecting damaged buildings after a disaster. SF

by DR STUART CLARK
(@DrStuClark)
Stuart is a space and astrophysics writer. His latest book is Beneath The Night *(£12.99, Guardian Faber).*

ABOVE Bernhard Vodermayer and Riccardo Giubilato from the ARCHES team adjust LRU1

RIGHT Werner Friedl and Bernhard Vodermayer from the ARCHES team with LRU2

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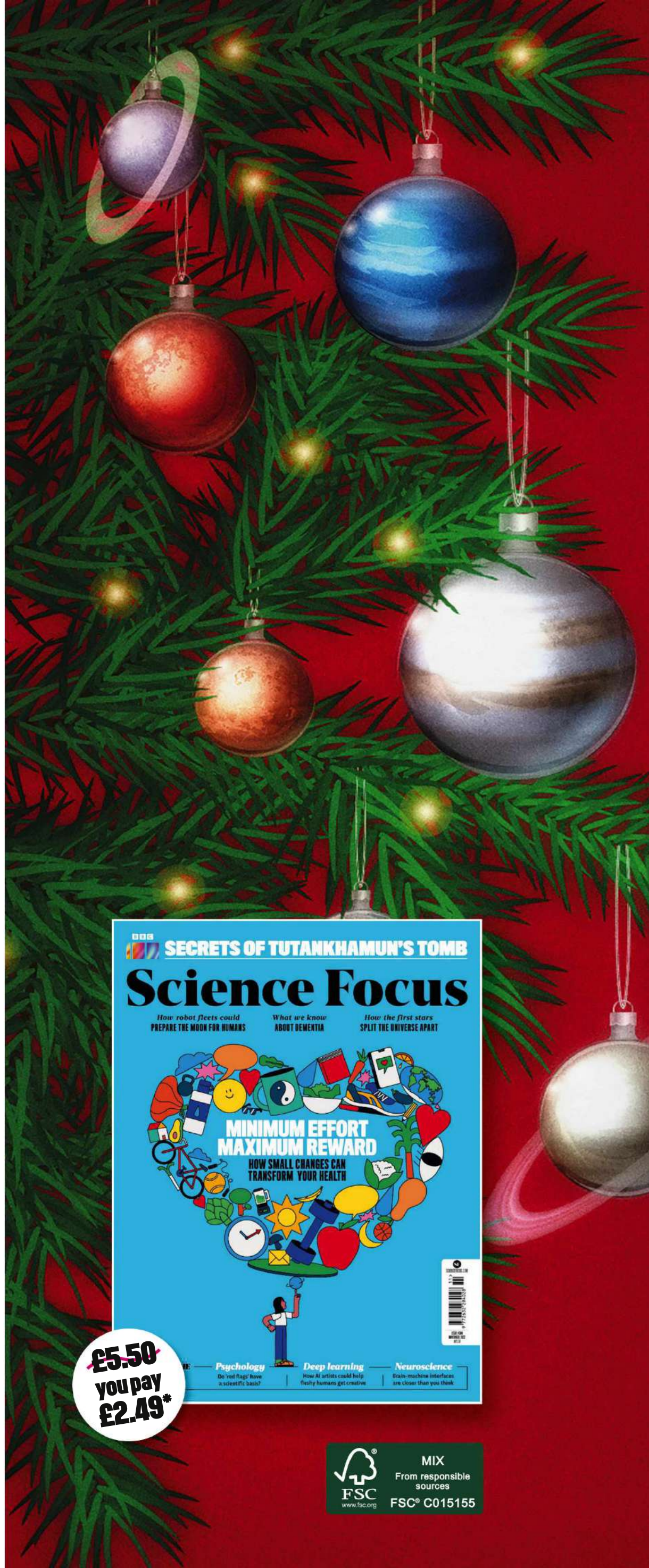

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MINIMUM EFFORT, MAXIMUM REWARD

Once you turn 30, things go downhill… fast. Your health, happiness and wellbeing all take a hit, and never really recover. So says conventional wisdom, anyway. Science, however, says otherwise. With a few small changes, you can make a big difference to the way you feel

Words **JAMES WITTS** Illustrations **ANDREA CHRONOPOULOS**

Time, they say, waits for no man. It also doesn't hesitate to start chipping away at your adult form. One minute, you're in your 20s and your body and brain are seemingly impervious to the clock and any debauched lifestyle choices you may be making. The next, you've tipped over into your 30s and everything changes. Fat begins to cling on due to you consuming more calories than you're burning. Your bone density starts declining faster than you can rebuild it. But, says the prosaically titled 2004 paper 'Muscle tissue changes with ageing' in the journal *Current Opinion In Clinical Nutrition And Metabolic Care*, "One of the most striking effects of age is the involuntary loss of muscle mass, strength and function, termed sarcopenia. Muscle mass decreases approximately 3 to 8 per cent per decade after the age of 30 and this rate of decline is even higher after the age of 60."

So what should you do? Roll over and accept your inevitable deterioration? Of course not. Here are some easy nutritional, physical, psychological and sociological ideas to help you be your best self… for a little bit longer, at least.

ILLUSTRATION: ANDREA CHRONOPOULOS

EAT MORE FIBRE

What

Fibre is so potent it's practically magic. Eating enough roughage can help you stave off heart disease and diabetes, and keep your guts in good nick. And the data is pretty conclusive.

A 2019 study in *The Lancet*, which involved "135-million person-years of data from 185 prospective studies and 58 clinical trials with 4,635 adults", suggested those eating sufficient fibre reduced their chances of conditions like type 2 diabetes, while strokes plummeted by 15 to 50 per cent. "Fibre also lowers the level of inflammation in the gut," says Peter Cronin of the University of Limerick, who's an expert on gut health. "Inflammation is an important factor in common intestinal diseases, such as colorectal cancer or inflammatory bowel disease. So, fibre has a protective effect against the development of these diseases." In fact, a 2015 analysis published in the *American Journal Of Epidemiology* showed that every 10g fibre consumed cut mortality risk by 10 per cent.

Why?

Fibre is a type of complex carbohydrate that the body can't break down. Fibre was once thought of as a major tool in keeping your stools regularly deposited and well-formed, but now scientists have discovered that there are further benefits to filling up on fibre. "Just like any living organism, the gut microbiota need nutrients to survive," Cronin explains. "Certain species of bacteria thrive in the presence of fibre as they've evolved to break down and use it as a nutrient source. Increased fibre intake leads to higher levels of these bacteria and lower levels of other species that are unable to use fibre as a nutrient source."

The benefits to the body are many, says Cronin. "When bacteria break down fibre in the gut, they produce short-chain fatty acids. This family of molecules [short-chain fatty acids] has a beneficial effect on the metabolism by lowering the level of lipids – cholesterol, for example – and glucose in the blood. These factors are associated with many diseases like obesity." By lowering the amount of 'bad' cholesterol in your blood, which can block blood vessels, you'll have a happy heart and reduce your chances of a stroke.

How?

You should aim for around 30g fibre each day. This is even more important as you grow older because of the increased risk of the diseases mentioned above. As you've probably predicted, processed foods are a no-no as the grain-refining process removes the outer coat (bran) from the grain, lowering its fibre content. "Instead, go for porridge oats, nuts, seeds, fruit and vegetables," says Cronin. "Fibres come in many forms, so mixing up different sources is best for gut bacteria health." What does 30g look like? Well, consume one avocado (6.7g of fibre), a cup of lentils (13.1g of fibre) and 100g of popcorn (14.4g of fibre) and you'd have more than covered your daily intake. But refrain from mixing together.

"JUST LIKE ANY LIVING ORGANISM, THE GUT MICROBIOTA NEED NUTRIENTS TO SURVIVE"

SLEEP LONG, LIVE STRONG

What?

Sleep is the best medicine. It boosts physical and mental health, and is so important that Tour de France winners are the ones deemed to have slept best over the 21 stages and 3,500km of racing. Which is a shame for those over 30…

Over the last four decades, the average age of parents having their first child has risen to 33.2 years for men and 30.3 years for women. Another way to put it is over the past 40 years, human beings have delayed the spectre of relentless sleepless nights. You see, a 2019 study in the journal *Sleep* found that new parents faced up to six years of sleep deprivation.

The cumulative long-term effects of a lack of both sleep quality and quantity is associated with a wide range of health consequences, including an increased risk of hypertension, diabetes, obesity, depression, heart attack and stroke. "It also lowers your immune system and is detrimental to mood and cognitive ability," says Prof Shona Halson from the Australian Catholic University.

GETTY IMAGES X2

Why?

Many of the sleep-impaired physiological issues are due to hormones. Take human growth hormone (HGH). This repairs muscles by stimulating the liver and other tissues to make a protein called 'insulin-like growth factor 1'. Lack of sleep equals lack of HGH production equals restricted muscle growth. (Alcohol has long been known to stall your secretion of HGH, with a study from 1980 showing alcohol decreased HGH secretion by 25 per cent.)

"Sleep also affects your eating habits by affecting the hormones that control eating behaviour," adds Halson. For instance, rising levels of a hormone called ghrelin signal that it's time to start eating, while increased levels of the hormone leptin tell you that you're full. A German study, published in the *Journal Of Sleep Research*, showed that just one night's broken sleep significantly raises ghrelin levels, explaining why you crave a tube of Pringles when you're tired. They also showed that two nights or more poor sleep reduces leptin levels.

How?

Strangely, babies aren't receptive to a tête-a-tête about their erratic sleep patterns. So if it's an option, work with them not against them. "Napping can be important if you're sleep deprived," says Halson. "A recent review of all the available napping literature found that the optimal nap duration was 20 to 90 minutes between 1pm and 4pm."

Whether you have kids or not, keep as consistent a bedtime as possible, avoid caffeine in the afternoon and banish your smartphone from your bedroom. "For people who are stressed or anxious, apps focused on relaxation or breathing may be useful, too," says Halson. "And you could try tryptophan-rich foods like milk. There's evidence – albeit sometimes conflicting – that this amino acid can help you sleep." Finally, don't go to bed full or having drunk a pint of water, as you'll wake up needing a wee.

DON'T STOP MOVING

What?

It's irrefutable – for a longer life, get moving. That was the message from a 2019 study in the *British Medical Journal* that showed 25 minutes per day of moderate exercise, like brisk walking, boosted the subjects' chances of living. The most sedentary group were 60 per cent more likely to die prematurely than the most active group.

This isn't wonderful news, as, according to a 2015 study co-commissioned by Public Health England, British people sit for an average 8.9 hours each day. Further research that same year in the *British Journal Of Sports Medicine* suggested there's a 5 per cent increased risk of premature death with each additional hour off your feet.

Why?

"That's okay," you might be thinking. "I have been manacled to a desk for the last 10 years, but I've just bought a standing one, so I'm all good." But hold your horses…

"There's evidence for some benefits of standing versus sitting at work for metabolic health, particularly how your body deals with sugar in your blood, which is an important factor in risk for diabetes and heart disease," says Dr Richard Pulsford, senior lecturer in physical activity and public health at Exeter University. "However, these benefits tend to be noticeable in those who don't live active lives or who are in poorer health."

Plus, while there is evidence that standing desks can help back pain, standing too long with a hunchback posture will only accentuate the symptoms. "It's inescapable," says Pulsford, "you need to move more."

"Movement's an important component of healthy ageing," he continues. "Ageing affects our metabolic processes and cardiovascular health, so anything we can do to support them – from exercising and keeping fit, through to moving little and often during otherwise inactive days – is beneficial."

How?

This doesn't mean you need to mimic Eliud Kipchoge and start running sub-two-hour marathons. Dancing, gardening, swimming… anything that gets you moving counters the effects of sitting for long periods, no matter how insignificant. "[The benefits of] breaking up your day with bouts of walking are certainly more pronounced than simply standing," says Pulsford. "In a recent study we found that intermittent slow walking, of two minutes every 20 minutes, reduced insulin demand and improved glucose uptake [both favourable metabolic changes for better health]. In the same study, intermittent standing didn't seem to make a difference. Exercising helps channel glucose from our blood – where it can cause damage if levels are too high – to our muscles and other tissues, where we can store it and use it later. The more we use in our muscles, the better."

"ANYTHING THAT GETS YOU MOVING COUNTERS THE EFFECTS OF SITTING FOR LONG PERIODS"

STRETCH AND STRENGTHEN

What?

Fact: cranking up your cardiovascular system bolsters health. But while walking, running and cycling are to be applauded, there's a powerful age-related case for stretching and strengthening. In fact, the American College of Sports Medicine and the American Heart Association recommend "muscular strengthening and flexibility activities at least two days per week for the maintenance of physical independence and health."

Why?

As we age, we lose muscle mass, which then kills off muscle fibres. Research has shown that the vastus medialis muscle in your thigh contains around 800,000 fibres when you're 20; by 60, it has 250,000. On average, we lose 8 per cent of our muscle fibres between 40 and 50, but that deterioration often starts earlier. That's especially true of 'fast-twitch' muscle fibres that are responsible for generating power (you also have 'slow-twitch' fibres that are more about endurance) and is why the fastest sprinters tend to be under 30.

Similar to sleep, your hormones are important here, especially testosterone, which preserves and increases lean muscle mass. Testosterone also improves cognitive function and increases bone density. The problem is, from the age of around 30, your testosterone levels begin to drop. That's where weight training comes in. It's an anabolic activity, meaning it generates higher levels of testosterone, which will counteract the natural drop as you age.

Flexibility is important, too. A paper in the journal *Sports Medicine And Health Science* investigated the association between flexibility and "the development of functional limitation" (the growing struggle to perform daily tasks). Out of the 1,318 adults studied, the 491 that undertook regular stretching exercises and the 122 that performed bodyweight exercises "were associated with 24 and 38 per cent decreased odds of incident functional limitation as they aged."

GETTY IMAGES X2

"ON AVERAGE, WE LOSE 8 PER CENT OF OUR MUSCLE FIBRES BETWEEN 40 AND 50, BUT THAT DETERIORATION OFTEN STARTS EARLIER"

How?

You don't need to morph into Dwayne Johnson or the She-Hulk. It's hard to be too prescriptive, but a couple of strength and stretching efforts each week is a good start. Just note that when it comes to strength training, squats are the ideal. They work a large range of muscles, including the gluteus maximus (your backside), one of the biggest muscles in your body. The bigger the muscle you work, the greater the testosterone hit.

As for stretching, dynamic stretches are regarded as being better than static ones for boosting strength and flexibility as they raise the temperature of the blood. Dynamic stretches are active movements where joints and muscles go through a full range of motion, while static ones are where you hold a stretch. You can do both types easily at home.

GET OUT OF THE HOUSE AND INTO NATURE

What?

If you're happy and you know it, clap your hands… and keep them clapping, as a study in *Proceedings Of The National Academy Of Sciences* found that people who had higher levels of optimism had a longer lifespan and were likelier to live past 85 in a healthy, joyous state. That's the good news.

Now for the bad. A 2010 survey by relationship-support charity Relate showed that people between 35 and 44 felt more depressed than any other age group. Long work hours, arguments and division of household chores were cited equally by men and women as the most common causes of problems. But there is a solution: head outdoors.

Why?

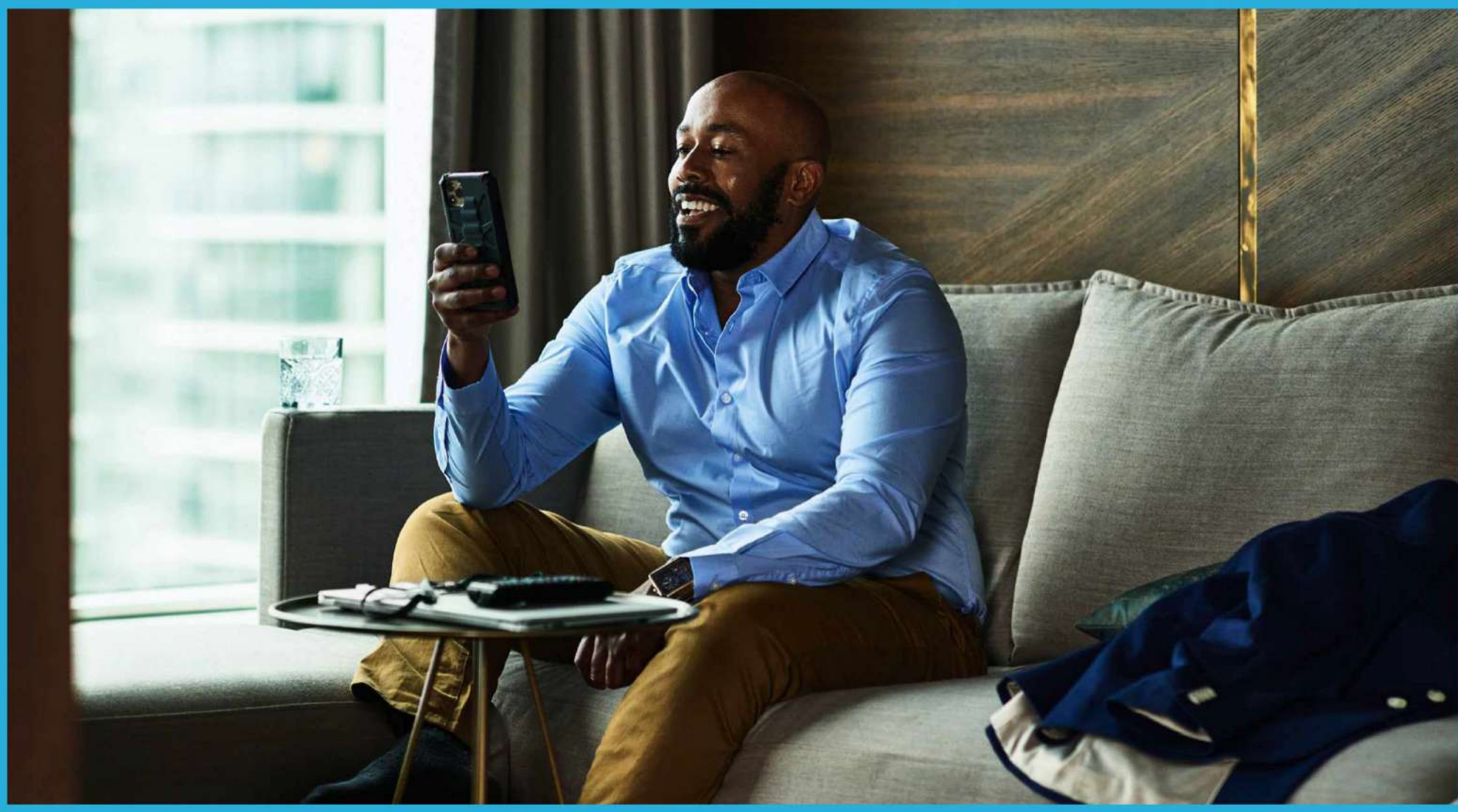
"Using data from nearly 20,000 people in England, we saw that those who spent more than two hours a week in nature showed consistently higher health and wellbeing than people who never visited," explains Dr Mathew White, an environmental psychologist at Exeter University.

These benefits are numerous and include six key mechanisms, says White. "Reducing exposure to environmental pollution, thanks to better air quality in places with more trees; exposing us to 'good' microbiota for healthy immune and gut function; encouraging 'capacity-building behaviours', such as promoting physical activity that's good for health; promoting social cohesion and good relationships, as nature seems to bring people together in positive ways; helping us to manage everyday stress by giving us less demanding contexts in which to collect our thoughts and restore depleted cognitive and emotional capacities; and building 'place attachment', which is important for people to orient themselves and find a place in the world."

How?

You don't have to go all Bear Grylls and camp out on a deserted island to enjoy nature's benefits. But, according to White, being beside a waterway – a sea, river or lake – confers the best of both worlds: green and blue space. "However, in our studies we've also seen the benefits of house plants and even virtual experiences via the television. Some studies also show the benefits of urban parks are strongest for those in more deprived communities, who may also have less access to more remote places due to costs and time."

"PEOPLE WHO SPENT MORE THAN TWO HOURS A WEEK IN NATURE SHOWED CONSISTENTLY HIGHER HEALTH AND WELLBEING"



STAY CONNECTED

What?

Loneliness is no laughing matter. But, once again, it appears longevity is, with a 2010 meta analysis showing that social support increases survival by up to 50 per cent, with research going back to the early 20th Century.

A more recent study by the Loneliness Commission, part of the Jo Cox Foundation, showed that men in particular are most likely to hit "peak loneliness" at 35 years old. This could be down to numerous factors, including unemployment, relationship break-ups, bereavement or moving away from family and friends. All of which are far from ideal, as a landmark study in the journal *Science* showed that lack of social connection is a greater detriment to health than obesity, smoking and high blood pressure.

Why?

Research has linked loneliness to greater risks of a number of physical and mental conditions, including high blood pressure, obesity, heart disease, depression, Alzheimer's disease and even death. The physiological, psychological and biological mechanisms at play are varied, but are rooted in the idea that loneliness alters the tendency of cells in the immune system to promote inflammation. Inflammation that lasts for significant periods of time increases the risk of chronic diseases.

This makes sense. Human beings are social creatures and, as a 2017 paper in the *American Journal Of Lifestyle Medicine* so acutely put it, "Social connection is a pillar of lifestyle medicine." The paper continued, "From psychological theories to recent research, there's significant evidence that social support and feeling connected can help people maintain a healthy body mass index, control blood sugars, improve cancer survival, decrease cardiovascular mortality, decrease depressive symptoms, mitigate post-traumatic stress disorder symptoms and improve overall mental health."

How?

Clearly there are many ways to connect, but the paper's authors suggest that, "It's safe to say that connecting with friends and family, with whom a person has a good relationship, is recommended on a daily, or at least weekly, basis. This could be a phone call, a Skype call or face-to-face interaction."

Experiencing a sense of belonging to a group is also beneficial, the study continues, and engaging in group activities once a week, or at least once a month, is an excellent place to start. SF

by **JAMES WITTS**
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James is a freelance science writer who specialises in health and fitness. His latest book is Training Secrets Of The World's Greatest Footballers *(£16.99, Bloomsbury).*

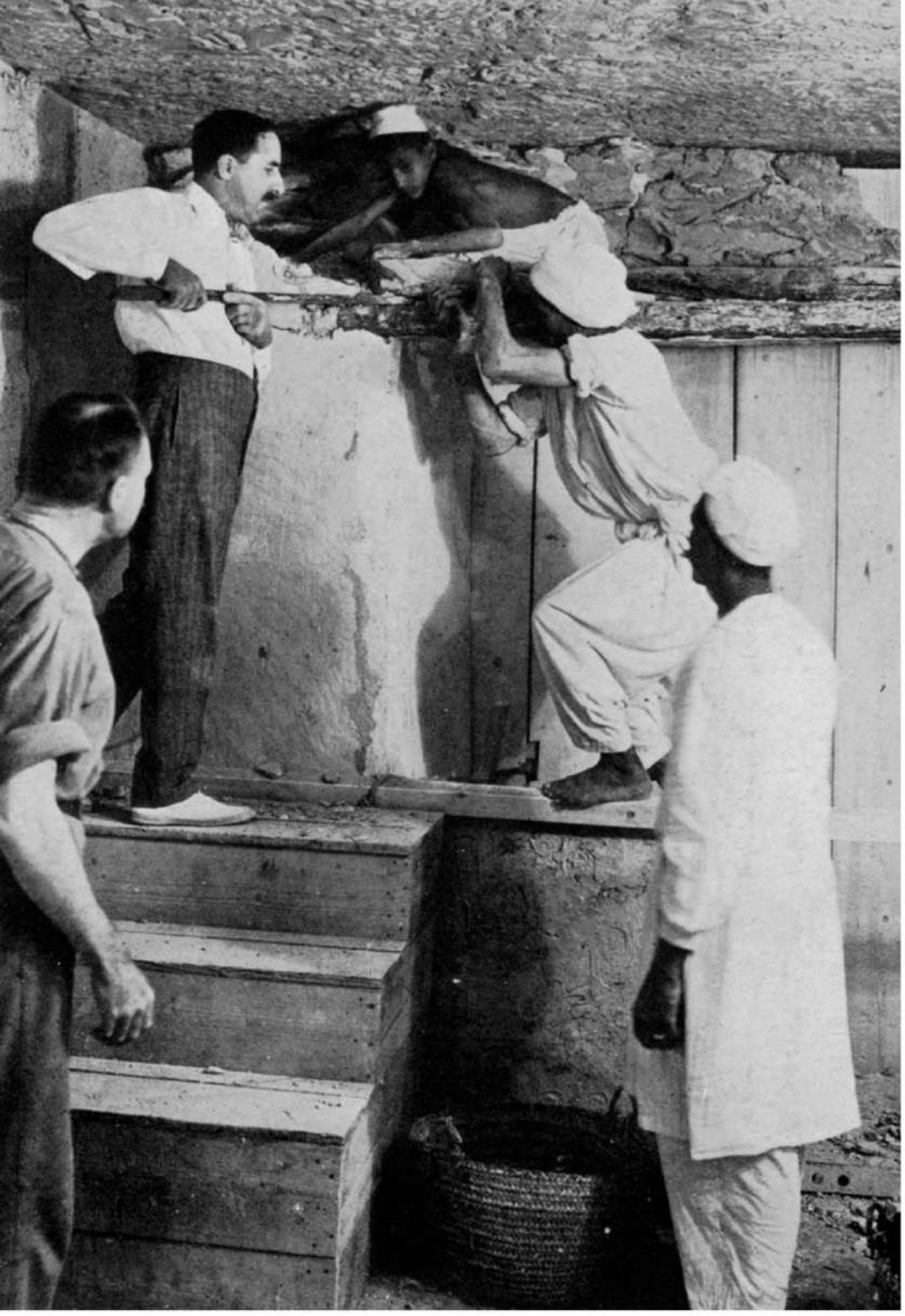
GETTY IMAGES X2

ESA

A century ago, Tutankhamun's tomb was discovered. But even today, controversy still rages over whether it contains undiscovered chambers. Here, an Egyptologist puts the rumours to bed… or, rather, firmly into their sarcophagus

by DYLAN BICKERSTAFFE

THE HIDDEN ROOMS OF TUTANKHAMUN'S TOMB



ABOVE LEFT
Egyptologist Howard Carter (at the top of the stairs) excavates Tutankhamun's tomb, with assistant Arthur Callender (at the bottom of the stairs) and Egyptian workmen

ABOVE RIGHT
Carter with the sarcophagus of Tutankhamun

On 26 November 2022, it will be 100 years since Howard Carter peered through a hole in the entrance to the chambers of Tutankhamun's tomb and saw "wonderful things". It was to be one of the greatest archaeological discoveries of all time.

Before Carter discovered the tomb in November 1922, Tutankhamun was an obscure pharaoh, but far from unknown. It was known that he had started life as Tutankh*aten* and had been married to Ankhesenpaaten, the third daughter of the 'heretic pharaoh' Akhenaten and the queen Nefertiti, and that he had ruled briefly under this name at the city of Akhet-Aten (modern Amarna, about halfway between Cairo and Luxor). This city had been founded by Akhenaten in honour of a single deity, the Aten. This abandoned Egypt's traditional polytheism of many gods presided over by 'the king of the gods', Amun-Ra.

However, after a few years, Tutankh*amun* changed his name in respect of the god Amun, and returned to the old religion (his queen becoming Ankhesen*amun* at the same time). He was known to have ruled for a total of about nine years. Despite this, his association with the heretic regime meant that later kings excluded his name from king-lists and usurped his name on monuments.

Carter was confident that Tutankhamun's tomb lay in the Valley of the Kings (at Luxor, in Upper Egypt), because a cache of leftover materials from the king's funeral had been found there in 1907. He was right, of course – it had been preserved under a thick layer of concrete-hard flood deposits.

Carter was a meticulous worker and recorded the location of every object in the tomb on plans and sketches, and through the fantastically detailed glass-plate negatives made by photographer, Harry Burton. At some point in its history the tomb had been affected by damp, which led to the spots of mould we see marring the wall-paintings in the burial chamber. The damp had also caused much warping and deterioration of wooden objects, and dissolved the glues, causing many items to fall apart. Carter's conservation team, led by Arthur Mace and Alfred Lucas, performed miracles to preserve the treasures we now admire today. In total, less than a quarter of 1 per cent of the tomb contents was lost.

Now, 100 years later, the artefacts are receiving state-of-the-art conservation in readiness for the opening of the Grand Egyptian Museum (GEM) in Giza, Egypt.

INTO THE TOMB

Visitors to Tutankhamun's tomb (numbered KV62) are invariably struck by how small it is – particularly when compared with great royal tombs such as that of Ramesses VI next door.

ALAMY, GETTY IMAGES, AKG IMAGES

ABOVE The death mask of Tutankhamun

> "THE MAGICAL STORY OF THE DISCOVERY HAS DRAWN LITERALLY MILLIONS OF VISITORS TO STAND IN THE TOMB"

Indeed, it is believed that KV62 was originally intended as the last resting place of a senior courtier, until it was rapidly adapted and pressed into service to house the prematurely deceased young king.

The treasures may now be in museums, but the magical story of the discovery has drawn literally millions of visitors to stand in the tomb over the years. The impact on the wall paintings of breath, sweat and dust brought in by these visitors created the need for an accurate replica of the burial chamber, allowing the original tomb to be periodically closed. To recreate the tomb, the Madrid-based company Factum Arte scanned the wall surfaces in incredible detail both in 3D and as colour images. Early in 2014 the results were made available online, where they can be viewed in colour or in relief, and examined in fine detail using the zoom facility.

It was scrutiny of the 3D images that led the Egyptologist Dr Nicholas Reeves to issue a paper in April 2015 suggesting that the walls of the burial chamber concealed hidden rooms. On the west wall he thought there were faint outlines of a sealed doorway, and in the main north wall still fainter traces of a partition wall with a service doorway in the centre. This was remarkable enough, but what really caused a sensation was his claim that the beautiful queen Nefertiti lay buried in a hidden chamber beyond. It was a story made for the media, and there were many in the Egyptology community who felt it was just too good to be true.

It is now generally accepted that Nefertiti reigned briefly as King Neferneferuaten (a name-extension she employed while still queen) as a regent, perhaps of Akhenaten, or for the young Tutankhamun. Reeves's claim that she lay behind the north wall was based on re-identifying the images of Tutankhamun as Nefertiti, and the figure of his successor, Ay (shown ritually 'opening the mouth' of Tutankhamun), as Tutankhamun himself.

Reeves drew support for these re-identifications from the examination of paint and plaster layers made by the Getty Conservation team involved in cleaning and restoration work. They revealed that, while the four walls each differed in some respect, the north wall showed evidence of having been reworked. The yellow ➤

background colour seen on the other walls had in this case only been filled-in around the human figures later – the original base having been white.

Of the two 'doorways', the one in the western wall is the more convincing, and the most obvious feature in the northern wall is a large fault in the rock a little left of centre with some associated restoration. It should be borne in mind that the 3D scans are so sensitive that they show up the thickness of paint outlining figures, and there are a lot of other lines on the walls.

DIGGING DEEPER

There was an almost universal call for wall-scans to settle the issue of whether there were any hidden chambers. Ground Penetrating Radar (GPR) scans of the burial chamber walls were carried out in late November 2015 by Hirokatsu Watanabe, a colleague of Reeves, using rather antiquated, customised equipment. His results were never formally published, and the initial press releases were greeted with some scepticism because Watanabe not only claimed to have found voids, but also evidence that these voids contained metal and organic materials – something which several experts pointed out was beyond the capabilities of GPR. What was not noted at the time was that both the voids and the materials within them had supposedly been found extending into areas not predicted by Reeves.

Although supported by Mamdouh Eldamaty, who was the Egyptian Minister of Antiquities at the time, the scans released

"THE 3D SCANS ARE SO SENSITIVE THAT THEY SHOW UP THE THICKNESS OF PAINT OUTLINING FIGURES"

to the press drew negative reactions from experts. In March 2016 Dean Goodman, who developed the GPR-SLICE software stated: "If we had a void, we should have a strong reflection. But it just doesn't exist."

In March 2016 a new Minister of Antiquities, Khaled el-Anany, permitted a second set of scans to be conducted by Eric Berkenpas and Alan Turchik for the National Geographic Society. These were much more thorough. First scanning a wall with a known void behind it to use as a

CLOCKWISE FROM BELOW The Nefertiti Bust, which dates back to 1345 BC; Egyptologist Nicholas Reeves entering the tomb of Tutankhamun; extensive scans carried out in the tomb in 2018 found no hidden voids

DYLAN BICKERSTAFFE, GETTY IMAGES X6, KENNETH GARRETT X2, ALAMY X2, THEBAN MAPPING PROJECT

model, they took 40 scans at both low and high frequencies, and at differing heights. A report was issued to the Antiquities Service, who formally announced in May that no voids had been found.

In February 2018, Francesco Porcelli from the Polytechnic University of Turin then led the most comprehensive set of GPR scans to date. After first establishing that they could pick up other chambers through the rock, three GPR systems with frequencies from 150MHz to 3,000MHz and dense spatial sampling were employed. But nothing was found.

"The existence of hidden chambers or corridors adjacent to Tutankhamun's tomb is not supported by GPR data," the team concluded.

Electrical resistivity and magnetic induction scans made from the surrounding ground surface did, however, pick up some shallow anomalies separated by some metres from Tutankhamun's tomb. Similar work by the UK company Terravision Exploration found a 'corridor-like' anomaly, about two metres high and 10 metres long, running to the north and parallel with the entrance passage to KV62. There is some suspicion that the air-extraction system in the tomb is creating a false reading here. In any case, a void such as this is unlikely to reveal a burial of Nefertiti.

In 2019 Reeves attempted to resurrect his idea with a fresh paper. Included was a reassessment of NGS scan data by George Ballard of the company Geotechnics, who believed he could see evidence of a rubble-filled passage behind the north wall. But if there was a wall with rubble behind it, this could simply be a case of work being cut short at the death of the pharaoh. If Nefertiti had once been buried in KV62, then she probably lay where Tutankhamun was later found. We know that he took items from her funeral goods for himself, including perhaps the sarcophagus, so maybe he simply displaced her.

While for most people it is case closed, there are still those who cry "just drill a hole". They invariably propose a hole drilled into the area behind the north wall from the adjacent treasury chamber. And if that hole failed to find anything, they would simply say, "drill another… " SF

by DYLAN BICKERSTAFFE
Dylan is an Egyptologist, lecturer and writer, with a special interest in the royal mummies.

A TIMELINE OF TUTANKHAMUN'S TOMB (KV62)

1323 BC
Tutankhamun dies and is buried in the Valley of the Kings.

26 Nov 1922
Howard Carter looks into KV62 and sees "wonderful things".

16 Feb 1923
Carter opens the KV62 burial chamber (and adjacent treasury).

Spring 1932
Last items from KV62 conserved and sent to the Egyptian Museum in Cairo.

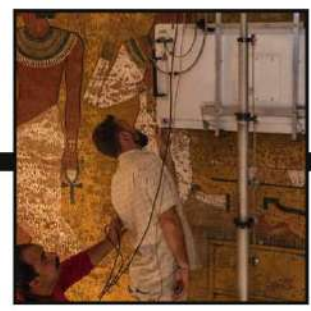
Mar-May 2009
Factum Arte scans the burial chamber paintings and sarcophagus in digital 3D.

2009
Getty Conservation Institute starts cleaning and conservation work, revealing evidence for differences in the plaster and paint sequences, for each of the four walls of the burial chamber.

26-27 Nov 2015
Scan carried out by Hirokatsu Watanabe, who claims there are voids in the walls.

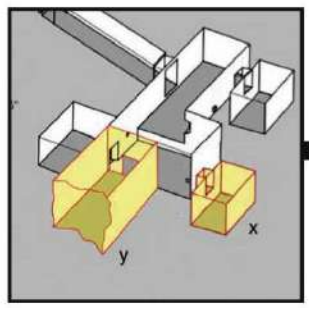
Apr 2015
Nicholas Reeves issues his paper, 'The burial of Nefertiti?'

Mar 2016
National Geographic Society carries out scans, and finds no voids.



Feb 2018
Extensive high-tech survey led by Francesco Porcelli finds no voids.

2019
Nicholas Reeves issues 'The burial of Nefertiti II'.



2020
Terravision carries out scan near KV62, and finds a corridor-like anomaly.

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Q&A

YOUR QUESTIONS ANSWERED

... WHY DO SOME PEOPLE GET SO DEFENSIVE?
... IS THERE A LANGUAGE OF LAUGHTER?
... HOW DIFFERENT WOULD EARTH BE ON THE OUTSIDE, IF IT WASN'T HOT ON THE INSIDE?
... CAN BABY BIRDS REALLY IMPRINT ON HUMANS?
... IS THERE A LANGUAGE OF LAUGHTER?
... WHY IS MY FITBIT GIVING ME A RASH?
... WHAT IS NORDIC WALKING AND IS IT GOOD FOR YOU?
... WHAT IS THE LIFE CYCLE OF A HOUSE SPIDER?
... HOW DO WE KNOW HOW DINOSAURS MOVED?
... WHAT IS TOXIC POSITIVITY?
... WHAT IS HIPPOPOTOMONSTROSESQUIPPEDALIOPHOBIA?
... WHAT WOULD THE NIGHT SKY LOOK LIKE IF WE LIVED IN A GLOBULAR CLUSTER?

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Science writer

ILLUSTRATION: DANIEL BRIGHT

AGNES CUNNINGHAM, FIFE

HOW MUCH CHEESE IS TOO MUCH CHEESE?

Your stomach is likely to tell you when you have reached peak cheese, but there is no exact measure of how much is too much. Cheese is packed with healthy protein and calcium but is also high in saturated fat and salt. According to the British Heart Foundation, a 30g portion of Cheddar can contain more salt than a packet of crisps. High levels of saturated fat generally drive up cholesterol and increase the risk of developing cardiovascular disease. However, there is growing evidence that cheese has a 'matrix effect' that protects us somewhat from the adverse effects of saturated fat. Most cheeses are prepared using an enzyme called chymosin to coagulate milk. Some fresh cheeses, like cottage cheese, are made using acid. Others, such as paneer, use a combination of heat and acid. How the cheese has been made will affect how your body digests it.

A Canadian study in 2017 on 43 healthy volunteers showed that fat from cream cheese was more rapidly digested and absorbed than from Cheddar. The researchers suggested that the small fat droplets in the cream cheese may be more accessible to the body's fat digesting enzymes.

In 2018, a separate study run by a team at University College Dublin found that consuming cheese gave rise to significantly lower cholesterol levels than when its components were eaten separately as butter, protein and calcium. So let the matrix effect be your excuse to indulge. ***ED***

ANUSHA KAPOOR, VIA EMAIL

WHY DO SOME PEOPLE GET SO DEFENSIVE?

As flawed beings with fragile egos making our way in a hostile, unpredictable world, psychologists have long recognised that we cope by deploying psychological defences. These often take the form of self-serving cognitive biases. For instance, we're prone to the 'better-than-average' effect, whereby we think we're better than most others at various skills from driving to maths; or we'll tend to attribute other people's successes to good luck, while seeing our own good results as a sign of innate talent.

Getting defensive when we're criticised, or when we make a mistake, is yet another of these self-protective mechanisms. As the politicians so often say: "mistakes were made, but not by me".

So, when you give someone negative feedback or you criticise them or their beliefs, you are – perhaps unwittingly – threatening their psychological defences. By forcing them to recognise how they've erred, you're likely to trigger extremely uncomfortable social emotions, such as a shame, guilt or embarrassment, or scary thoughts of rejection or loss of status. A way for people to avoid these uncomfortable feelings and thoughts is to get defensive, to deny they did anything wrong, to double-down on the moral superiority of their view or engage in the mental gymnastics needed to save face.

Support for the social and moral aspects of defensiveness comes from a study by psychologists at Australia's University of Flinders in 2020. The researchers showed that volunteers' defensiveness (about past mistakes or possible moral transgression) was intensified if they'd just had an experience of being socially rejected – thus rendering their egos more vulnerable. Conversely, the volunteers acted less defensively if they'd had an earlier opportunity to express their moral values, which would have made them feel more secure about their moral standing.

One practical takeaway from all this is that when you're giving negative feedback, it pays to consider the effect it may have on the other person's delicate self-esteem. Therefore, focus your criticism on what they did wrong, not on their personality or character. You can also take some of the sting out by concentrating on how their mistake can be fixed or how they can improve next time, that way they're less likely to take things so personally. ***CJ***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

IS THERE A LANGUAGE OF LAUGHTER?

Laughter is a human universal – something all people do in every corner of the globe, no matter their culture. There's evidence that it can act as a social glue, encouraging shared feelings of closeness.

But of course, that doesn't mean that we all laugh the same amount, at the same things or in the same situations. In fact, psychologists in Canada have proposed a theory that says there are four main styles of humour, and that individuals and cultures vary in how much they tend to practise and laugh at these different kinds of joke. It's almost as if we speak different laughter languages, depending on the mix of our own personality and cultural background.

The four humour styles are: affiliative (laughing with other people and amusing them); self-enhancing (managing to take a light-hearted approach to difficult circumstances or setbacks); self-defeating (making fun of oneself for other people's amusement, to manipulate or hide one's true feelings); and aggressive (ridiculing or teasing other people).

In terms of links with personality, there's evidence that friendly, cheerful extraverts tend to go for self-enhancing and affiliative humour; in contrast people who are moodier and less agreeable tend to practise more aggressive and self-defeating humour.

When it comes to cultural differences, studies show that people from more collectivist cultures, such as China, are less likely to use aggressive humour and more likely to use affiliative humour, compared to people from more individualistic cultures, such as the US and Canada. Other research has found that people from Eastern cultures are less likely to use humour as a coping strategy, and generally view a sense of humour as a less important attribute compared with how it's seen in the West. *CJ*

GETTY IMAGES X3, ALAMY ILLUSTRATION: DANIEL BRIGHT

B KIRKBY, VIA EMAIL

HOW DIFFERENT WOULD EARTH BE ON THE OUTSIDE, IF IT WASN'T HOT ON THE INSIDE?

Earth has been slowly cooling since it formed 4.5 billion years ago, and sometime between 1.5 and 0.5 billion years ago, the core began to crystallise into a solid ball of mainly iron and nickel. The core is growing by around one millimetre per year, and at that rate, Earth won't have time to fully cool and solidify before the Sun reaches the end of its life in around five billion years, when it'll expand and potentially engulf the planet we live on. If some currently unknown mechanism caused Earth to cool much sooner, it would have serious long-term consequences for most life on the planet. Without the electric dynamo of the molten outer core, Earth's magnetic field would fade to zero, and the stream of charged particles from the Sun, known as solar wind, would begin stripping away the atmosphere, as may have happened to Mars long ago.

For Earth to have already cooled by now, it would have to be much smaller. Gravitational compression and friction will heat any planet-sized body, and radioactive decay from elements in the mantle will add to this heat. The Moon is thought to have been formed from the impact of a Mars-sized body called Theia with the early Earth, around 4.5 billion years ago. The energy of the collision would have meant that Earth and the Moon would have both started out mostly molten, but the Moon cooled much more rapidly because it's smaller. A smaller, cold Earth would have lacked the volcanoes and plate tectonics that have recycled carbon and minerals in the crust and added gases to the atmosphere. Without a thick atmosphere, the surface temperature would drop low enough to freeze the ocean. It's doubtful that life – at least, complex life – would have evolved in these conditions. ***LV***

GARY SIMMS, VIA EMAIL

CAN BABY BIRDS REALLY IMPRINT ON HUMANS?

Imprinting is a survival strategy that occurs when a newly hatched bird sees another animal and then forms a strong attachment to it. Usually it's the baby's mother, but sometimes it can be an inanimate object, such as a stick, or a different animal, such as a human. The most impressive demonstration of this has to be from Italian hang glider pilot Angelo d'Arrigo. He reared a flock of Siberian cranes under the wing of his hang glider, and then in 2003, guided them all the way from northern Siberia to the Caspian Sea in Iran; a journey of 5,500km. ***HP***

MARJORIE EASTMAN, CHESTER

WHY IS MY FITBIT GIVING ME A RASH UNDER THE STRAP?

The Fitbit rash first made headlines back in 2014 – there was a nationwide recall of the Force wearable fitness tracker due to reports of a wrist rash. Today, many Fitbit wearers continue to report rashes with the company's latest line of fitness trackers. It might be due to contact dermatitis, which is a reaction that can occur anytime there is constant friction, pressure and sweat between the skin and another item, or possibly an allergic reaction related to a substance in the strap itself. According to Fitbit, the following four measures can help: keep your Fitbit clean; keep it dry; don't wear it too tightly; give your wrist a rest by removing the band for an hour after extended wear. ***NM***

WILL MOON, VIA EMAIL

WHAT IS NORDIC WALKING AND IS IT GOOD FOR YOU?

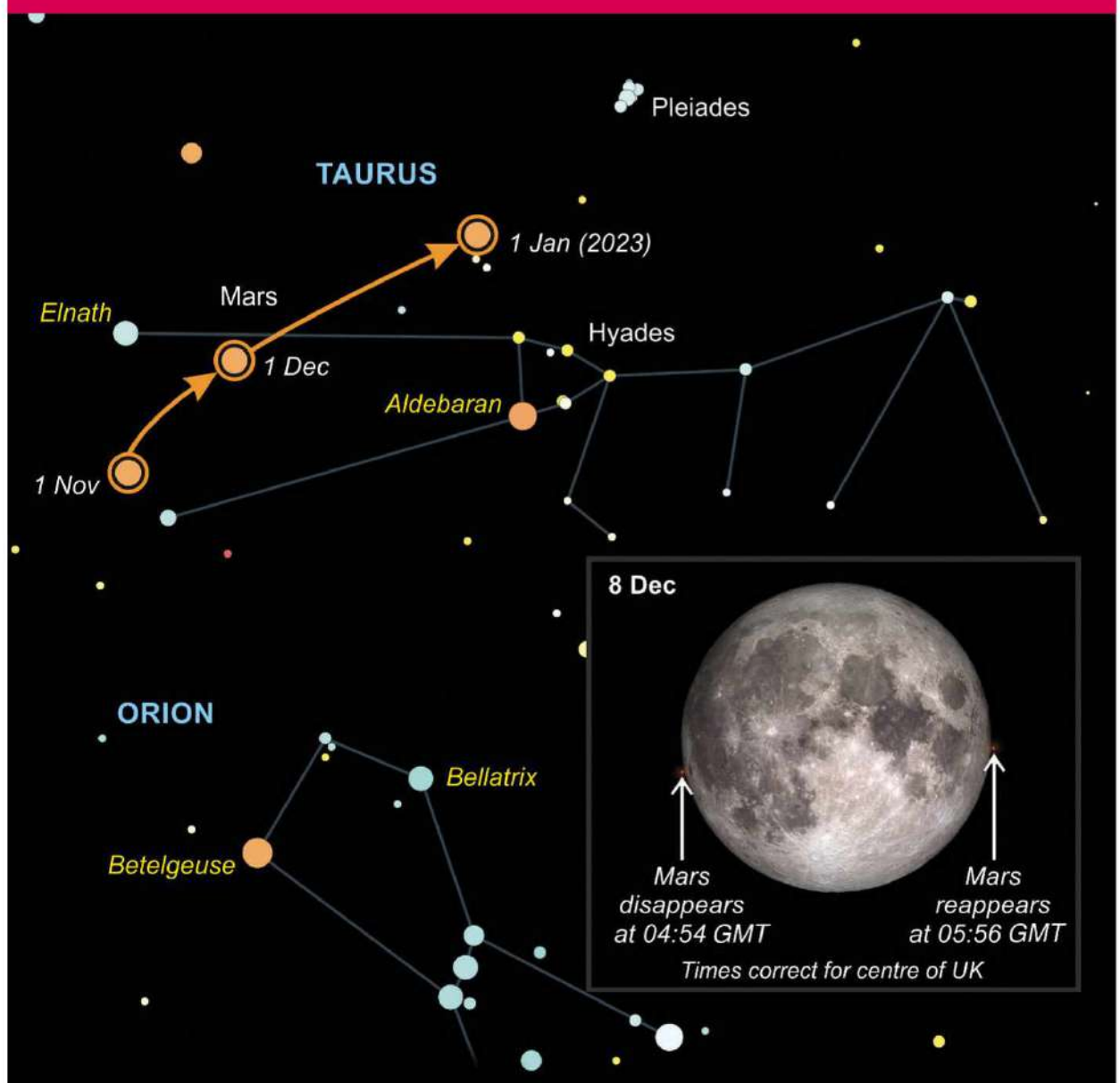
Nordic walking is a type of low-impact exercise that uses specialised poles and striding technique to engage all the body's major muscle groups. It originated in Finland in the 1930s, as a way for cross-country skiers to train during the summer months. Since then, it's gained popularity around the world as a fun way for people of any age to get moving and out into nature.

Unlike hiking poles, which are typically held in front of the body to help with balance and stability, Nordic walking poles should only ever be in contact with the ground behind you. With each step forward, the opposing arm – held straight at the elbow – swings out in front you, dragging the pole gently along the ground. As you take your next step, you plant this pole into the ground and push down and back into it to help propel yourself forward.

The Nordic technique turns walking into a full-body workout, activating the muscles of the shoulders, back and core as well as the arms and legs. In fact, Nordic walking engages up to 90 per cent of the body's muscle mass! That means it's great for improving posture and cardiovascular health, as well as burning calories. Studies show that it can burn anywhere between 18 and 67 per cent more calories than standard walking or even light jogging.

At the same time, Nordic walking is gentle on the joints. The poles reduce the load on the lower body, and their design – lightweight and attached to the wrist with straps – allows the walker to relax their grip for part of each stride. Like any exercise, Nordic walking can help with stress management, and it offers the additional mental health benefits of being performed outdoors, often in social groups. Finally, almost anyone can do it; all you need is some comfortable, supportive shoes and a set of poles! ***CP***

ASTRONOMY FOR BEGINNERS



HOW TO SEE MARS IN WINTER

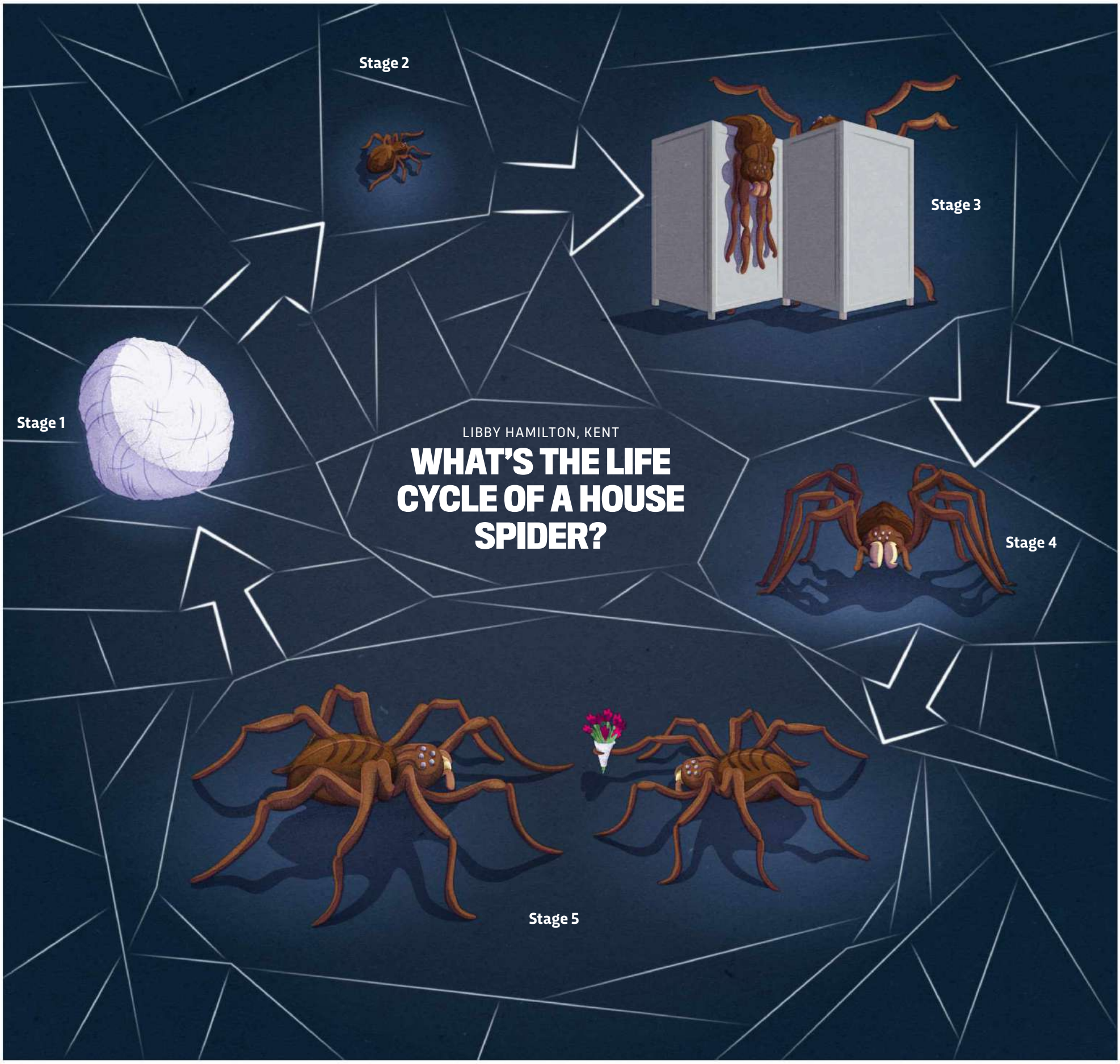
The planet Mars is becoming a major player in the night sky, outshone only by the Moon, when it's about, and Jupiter. It's visible, bright and distinctly orange in colour, above the eastern horizon at 11pm on 1 November, at 10pm mid-November, and at 9pm on 1 December. Mars is currently moving against the stars of Taurus the Bull, and this places it near two bright and similarly orange-hued stars, Aldebaran in Taurus and Betelgeuse in Orion.

After Earth, Mars is the next furthest planet from the Sun. It takes 687 days for the Red Planet to complete one orbit. This means that from Earth, it appears to lie in the opposite part of the sky to the Sun, a position known as opposition, once every 2.1 years. Opposition is a big deal for Mars, because apart from putting a planet in a position where it's visible all night long, this is also when it appears brightest and, through the eyepiece of a telescope, largest. All superior planets – the term describing planets with larger orbits than Earth – reach opposition, but the improvement in visibility is particularly dramatic for 'nearby' Mars.

Mars reaches opposition on 8 December, and the Red Planet is closest to Earth a week earlier, on 1 December. Excitingly, from the UK in the early hours of 8 December, the full Moon appears to move in front of Mars, hiding it from view; a rare event known as a lunar occultation of Mars. This event will be visible to the naked eye, as well as through binoculars and telescopes. From the centre of the UK, Mars disappears at 4:54am, before reappearing just over an hour later at 5:56am.

Times will vary slightly with different locations, so start viewing approximately 20 minutes before the stated times to ensure you don't miss anything. *PL*

GETTY IMAGES X2, ESO ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT



LIBBY HAMILTON, KENT

WHAT'S THE LIFE CYCLE OF A HOUSE SPIDER?

Stage 1: The egg sac
In the spring, female spiders start to produce egg sacs. These silky, cocoon-like constructions can each contain up to 70 eggs, and a female spider can produce as many as 10 egg sacs over her lifetime.

Stage 2: Spiderling
Juvenile spiders, known as spiderlings, hatch from the eggs and undergo their first moult inside their egg sac. When they're ready to emerge, they cut a hole in the sac and escape, temporarily staying close by before dispersing.

Stage 3: Moulting
Each spiderling must go through up to eight moults before they reach adulthood and sexual maturity. Before each moult, the spider withdraws to a quiet area and stops feeding for a few days. Beneath its outer layer, a new, softer exoskeleton is forming while enzymes start to dissolve the inner surface of the old one, almost as if it's unfastening a suit made of Velcro.

Gradually, the old exoskeleton splits open, and the spider peels off the old 'suit'. The spider is soft and vulnerable but can expand in size while the new exoskeleton hardens.

Stage 4: Adult
Males reach adulthood and sexual maturity in late August and September after their last moult. It's at this time of year we see them running around our homes. It's a bit like the *Love Island* of the spider world, as house spiders try to couple up. Males roam looking for the more stationary females, picking up on chemical signals in the females' spider silk that let them know she's sexually mature.

Stage 5: Mating
Since spiders are carnivores, they've developed courtship rituals to ensure the female doesn't mistake the male for prey. Once the male has been accepted by the female, he'll co-habit the female's web before mating. The male uses organs called pedipalps, located near his mouth, to give the female his sperm. She stores the sperm in her spermathecae organs, until she is ready to produce eggs next spring. The male spider dies as winter approaches, while the female overwinters in her web. ***SO***

NATURE'S WEIRDEST CREATURES

RAINBOW SQUIRREL

With its chestnut bonce and flamboyant, technicolour body suit, this glam-rock rodent is certainly channelling its inner Ziggy Stardust. The aptly named 'rainbow squirrel', or Malabar giant squirrel, adds a welcome touch of pizzazz to the upper canopies of the forests in central and southern India. Compared to the UK's squirrels, they really are giant too. Adults weigh up to 2kg, the same as a small chihuahua, and grow up to a metre long, head to tail. They spend most of their lives off ground, leaping up to six metres between branches, and they cache their nuts and seeds in the trees, rather than on the ground.

The big question, of course, is why so bling? Surely, the squirrel's outrageous attire must act as a beacon for predators, such as crested serpent eagles and jaguars? The answer is that no one really knows. It could be a form of camouflage. Much like military fatigues, which use pattern and contrasting colour swatches to help the wearer blur into the background, so too the squirrel's contrasting colour blocks may help it to 'disappear' against the dappled mosaic of the forest canopy. Or maybe the getup helps the squirrel to attract a mate... by giving it the sex appeal of a rock god! ***HP***

IAN MCMAHON, SCUNTHORPE

WHAT IS TOXIC POSITIVITY?

Toxic positivity comes from the belief that, despite an individual's emotional pain or challenging situation, they should still adopt a positive outlook. It denies, invalidates and delegitimises emotions that aren't 'happy' and includes phrases such as "turn that frown upside down", "it could be worse" or, a social media favourite, "good vibes only".

Studies have shown that suppressing feelings can lead to increased stress, anxiety and depression in the long run. More effective is trying not to label emotions as 'good' or 'bad', instead recognising that it's okay to feel sad, angry or frustrated, and remembering that emotions will eventually pass. ***SO***

ADAM WORTHY, VIA EMAIL

WHAT IS HIPPOPOTOMONSTROSESQUIPPEDALIOPHOBIA?

It's the fear of long words. *Sesqui* is Latin for one and a half, and the phrase "sesquipedalia verba" was used as long ago as the first century BCE by the Roman poet Horace, to criticise writers who used words "a foot and a half long". Converting this into a fear of long words, should really only require us to add -phobia on the end, but the longer version appears to have been coined by the American poet Aimee Nezhukumatathil in 2000, who presumably added the extra syllables for literary effect. Like aibohphobia (fear of palindromes) this is an amusing wordplay, not a genuine medical condition. ***LV***

GARY, VIA EMAIL

HOW DO WE KNOW HOW DINOSAURS MOVED?

Tyrannosaurus rex lived 66 million years ago and no human has ever seen one alive. How do we know how it – or any other long-extinct dinosaur – moved? This is part of a larger question in palaeontology: how do we understand the behaviours of extinct species? In general, we rely on information from fossils, tests using computer modelling, and comparisons to modern-day animals, especially birds (the descendants of dinosaurs) and crocodiles (the closest living cousins to dinosaurs).

Fossils can tell us certain things about dinosaur movement. Simply by looking at a skeleton, we can grasp the basics of whether the dinosaur walked on all fours, or only on its hind legs. Skeletons can also give us an indication of whether a dinosaur was likely to be slow or plodding, based on how robust the bones are and how the limbs are held.

Even more accurate information comes from a different type of fossil: trace fossils. These are the records dinosaurs left behind, like footprints and handprints. The spacing between successive footprints can tell us how fast a dinosaur was walking or running, using a basic mathematical formula developed by studying modern animals. The gist of it is this: if you're walking slowly on a beach there'll be small spaces in between your footprints in the sand, but if you're running then the tracks you leave behind will be spread much farther apart.

More recently, palaeontologists have turned to computer modelling to understand dinosaur locomotion. We can use computer-assisted tomography (CAT) or laser scans to build an accurate model of a dinosaur skeleton, digitally add the flesh, muscle and other soft tissues based on comparisons to modern animals, and then use animation software to test whether certain speeds, body postures and running styles were possible. This type of work, for example, reveals that *T. rex* was far too large and bulky to run faster than about 10mph (16km/h). ***SB***

QUESTION OF THE MONTH

JAMES CRANNELL, VIA EMAIL

WHAT WOULD THE SKY LOOK LIKE IF EARTH REVOLVED AROUND A STAR IN THE CENTRE OF A GLOBULAR CLUSTER, LIKE MESSIER 15?

The view of the night sky from within a globular cluster would depend on your position within the cluster. This is because stars are packed together more tightly in the core of the cluster compared to the periphery. In the core of a typical cluster, the average distance between stars is about one light-year, compared to about five light-years in the solar neighbourhood.

Since the brightness of stars is inversely proportional to the square of distance, this means the brightness of stars in the night sky would be about 25 times what is seen from Earth. Now, on Earth, on a clear night, starlight has a brightness of about 0.001 lux (a unit of 'illuminance'). So, on a planet in the core of a globular cluster, the starlight would be about 0.025 lux. By comparison, moonlight at a full Moon is about 0.2 lux, about eight times brighter.

So, although the night sky on our imaginary planet will be bright, and undoubtedly crowded with stars, it will be much fainter than Earth's night sky during a full Moon. If our planet is similar to Earth, with a similar atmosphere, and is orbiting a star similar to the Sun, the daytime sky would be about 100,000 lux. So, our crowded night sky would still be drowned out by the daytime sky. ***AG***

WINNER

The winner of next issue's *Question Of The Month* wins an **Airthings Wave Mini**, worth £69. This mini indoor air quality monitor is perfect for monitoring mould risk, temperature, humidity and airborne chemicals. With four air quality sensors, you can create custom alerts and integrate with other smart home products.

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EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

ALAMY, GETTY IMAGES, ADAM BLOCK/WIKIPEDIA ILLUSTRATION: DANIEL BRIGHT

DEMENTIA

THE EXPLAINER

IT'S NOT AN INEVITABLE PART OF AGEING

ILLUSTRATIONS: MARK FRUDD

What is dementia?

Terry Pratchett, the author of the Discworld novels, described his dementia as an "embuggerance". "I've given up my driving licence because I didn't feel confident driving," he told the BBC in 2008, soon after he was diagnosed. "And if I've got something inside out, it's a little bit puzzling getting it the right way around again."

People with dementia may struggle with many aspects of their lives that we all take for granted, such as remembering new information, holding a conversation, decision-making, reading, writing and understanding times and places. Dementia is a disease that damages brain cells, leading to progressive deterioration in memory, thinking and communication, as well as personality changes.

Nearly 50 million people worldwide are living with the condition and numbers are expected to rise as the population gets increasingly older. About two-thirds of dementia cases are Alzheimer's disease, but there are over 200 other types of dementia. Even within these categories, patients may present in different ways. For example, some people may not know they have dementia or that their abilities are limited by it, while others will be aware, at least some of the time. However, as the disease progresses through its early, middle and late stages, more areas of the brain are involved and the symptoms of the different types of dementia start to look more similar.

Can you see dementia on a brain scan?

Yes and no. While MRI and CT scans are often used to confirm a diagnosis of dementia – following simpler question-and-answer tests – some of the changes to the brain that may be seen in dementia are also seen in other situations, such as menopause. So it's difficult to be absolutely sure. In fact, many people living with dementia haven't been formally diagnosed, and it's thought that more than a quarter of cases could actually be misdiagnoses.

In several high-profile cases, patients have been wrongly diagnosed with, and treated for, Alzheimer's disease. One example is Alex Preston, who was diagnosed in 2014 in Leicester, UK, and continued taking medication for seven years, until he discovered the diagnosis was wrong.

For a long time, the only way to confirm an Alzheimer's diagnosis was through an autopsy – you could only examine someone's brain after their death. Specialists can now spot signs of the disease through sophisticated brain imaging and sampling of spinal fluid, but these techniques are more often used in research studies than in clinics.

"Nearly 50 million people worldwide are living with dementia and numbers are expected to rise as the population gets increasingly older"

What causes dementia?

Brain cells (neurons) are damaged and die as part of the normal ageing processes. But for people with dementia, they lose many more neurons than they normally would, and this starts to happen before the symptoms even become apparent.

In Alzheimer's, the damage occurs when proteins clump together in abnormal ways, forming hard plaques and tangles between and inside brain cells. The plaques are composed of amyloid beta, which is present in healthy brains too, although we're not sure exactly what its role is. The tangles are made up of tau proteins, which usually work with structural supports called microtubules to give neurons their distinct shape. But in Alzheimer's the tau proteins separate from the microtubules and stick to each other to form long threads that block the cells and stop them passing vital nerve signals.

Current research is trying to unpick how the two types of protein interact, with suggestions that they may share a common 'seed' that kicks off the abnormal accumulations. Proteins are involved in other types of dementia as well, such as Lewy body dementia, where there is a buildup of alpha-synuclein protein. The brain may also be damaged by Parkinson's disease, or lack of blood supply (vascular dementia).

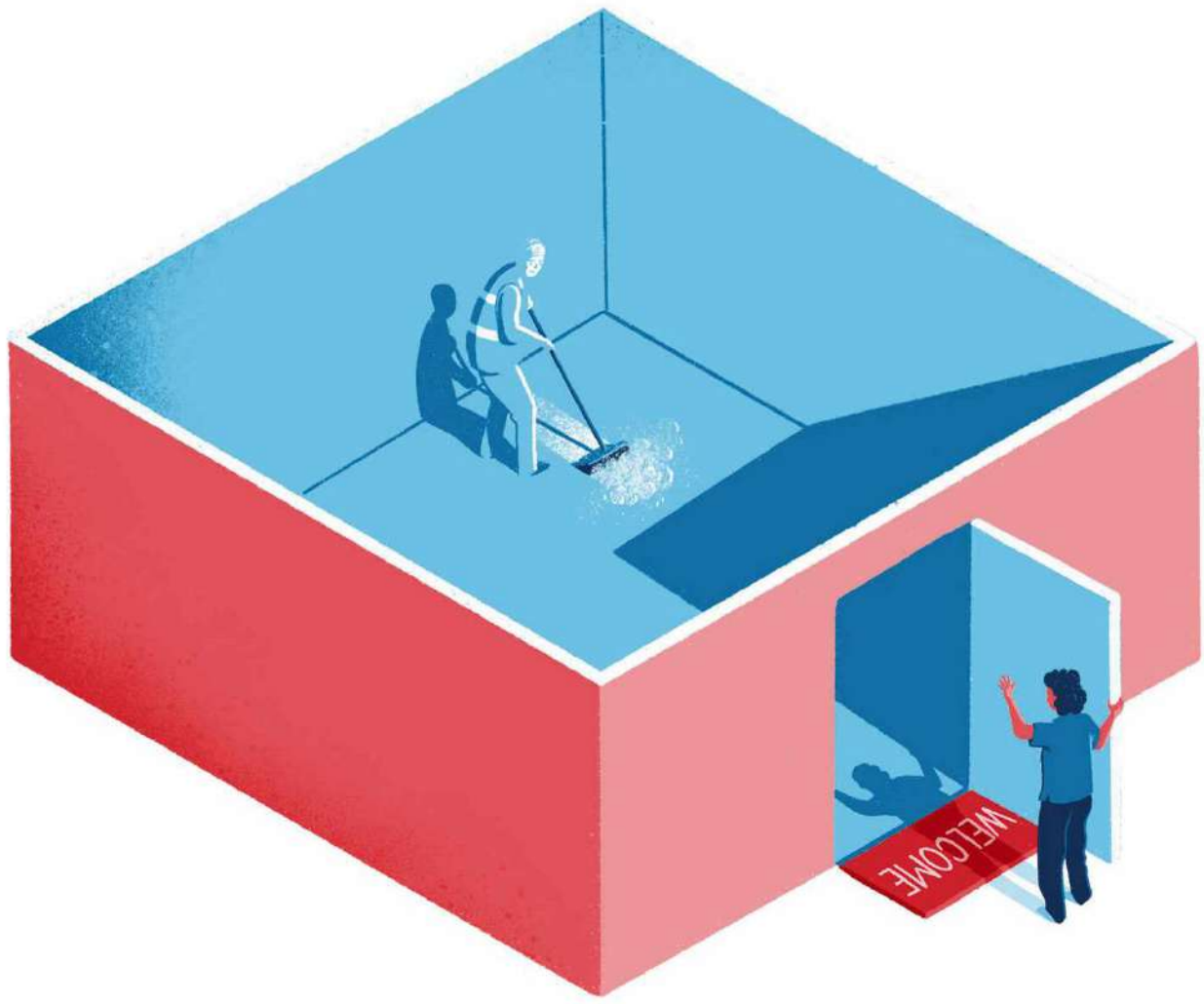
ILLUSTRATION: MARK FRUDD

“It’s not easy to say what makes one person more susceptible to the condition than another, though women do seem to be affected more than men”

Can anyone get dementia?

Dementia is fairly common. A 2020 study that looked at worldwide rates showed how the likelihood of having the condition increases with age. Although only about 70 people in every 1,000 are affected in the over-50s, anyone living to over 100 is more likely to have dementia than not, with around 660 of every 1,000 centenarians affected. Dementia before the age of 65 is usually referred to as early or young onset dementia.

It’s not easy to say what makes one person more susceptible to the condition than another, though women do seem to be affected more than men. A combination of genetic and lifestyle factors are thought to be at play. APOE is the perhaps the gene with the strongest association. But while one variation of the APOE gene carries a higher risk of Alzheimer’s, people with a higher risk may still never go on to have dementia because of differences in lifestyle. Lifestyle factors including education, diet and sleep habits are all thought to impact on your overall risk. Certain medical problems experienced in middle age, such as blood pressure, being overweight and heart problems, can also have an impact. There is even some evidence suggesting that living in an area exposed to more air pollution can increase your risk of dementia.



How should I talk to someone who has dementia?

The well-known neurologist and author Oliver Sacks wrote about a dementia patient at a nursing home who thought he was still working in his old job as a school janitor. The nurses accepted his internal reality, allowing him to clean, carry keys and make checks on the doors, windows and kitchen appliances, right up until his death from a heart attack. According to Sacks, the man died content – treating him otherwise would have been a pointless and cruel assault on his identity.

The nurses’ approach was in line with what dementia experts refer to as validation therapy, as opposed to old-style, reality orientation approaches, which try to ground the patient in reality by giving them information and reminders to fill the gaps in their thinking.

Following the validation approach means listening, accepting the person as they are without judgment, and focusing on their feelings and needs rather than anything we’d like to correct or change. Experts also advocate trust and respect – so maintaining a respectful tone of voice and eye contact are important.

Can we treat dementia?

Dementia cannot be cured. But experts hope that recognising the damage that leads to dementia before symptoms occur, may allow us to develop treatments that can slow the progression of the condition, or prevent symptoms occurring at all.

The main aim of the treatments available today is to help reduce the person's suffering, although there are also drugs and activities that are thought to benefit their brain. The most commonly prescribed drugs are called acetylcholinesterase inhibitors. These drugs help to increase levels of a key molecule – acetylcholine – involved in nerve signal transmission in the brain, by blocking an enzyme that usually destroys it. The action of these drugs can help to relieve some of the symptoms.

Meanwhile, some studies suggest that playing games like chess, doing exercise – both aerobic and strength training – and taking part in social events such as birthday parties, can help with maintaining better brain function for longer. Once the disease has progressed into the later stages, however, some of these activities may prove too stressful.

Family members often find themselves struggling to work out what's best for their relative. Caring for someone with dementia, and who sometimes doesn't recognise you, can be emotionally and physically draining, hence why charities like Dementia UK emphasise support for the whole family, not just the person with the diagnosis.

"The main aim of the treatments available today is to help reduce the person's suffering, although there are also drugs and activities that are thought to benefit their brain"

HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a freelance science writer and editor.

FIVE FACTS ABOUT DEMENTIA YOU SHOULD KNOW

1. We may all have the odd memory lapse as we get older, such as occasionally losing our car keys, but this is not the same as dementia, which is different from normal ageing.

2. The time it takes to get a dementia diagnosis doubles when the patient is under 65.

3. The APOE4 gene variant carries a three-fold greater risk of Alzheimer's disease if you have a copy from just one parent, and an eight-fold greater risk if you have copies from both. One in four of us have one copy, and one in 50 have two.

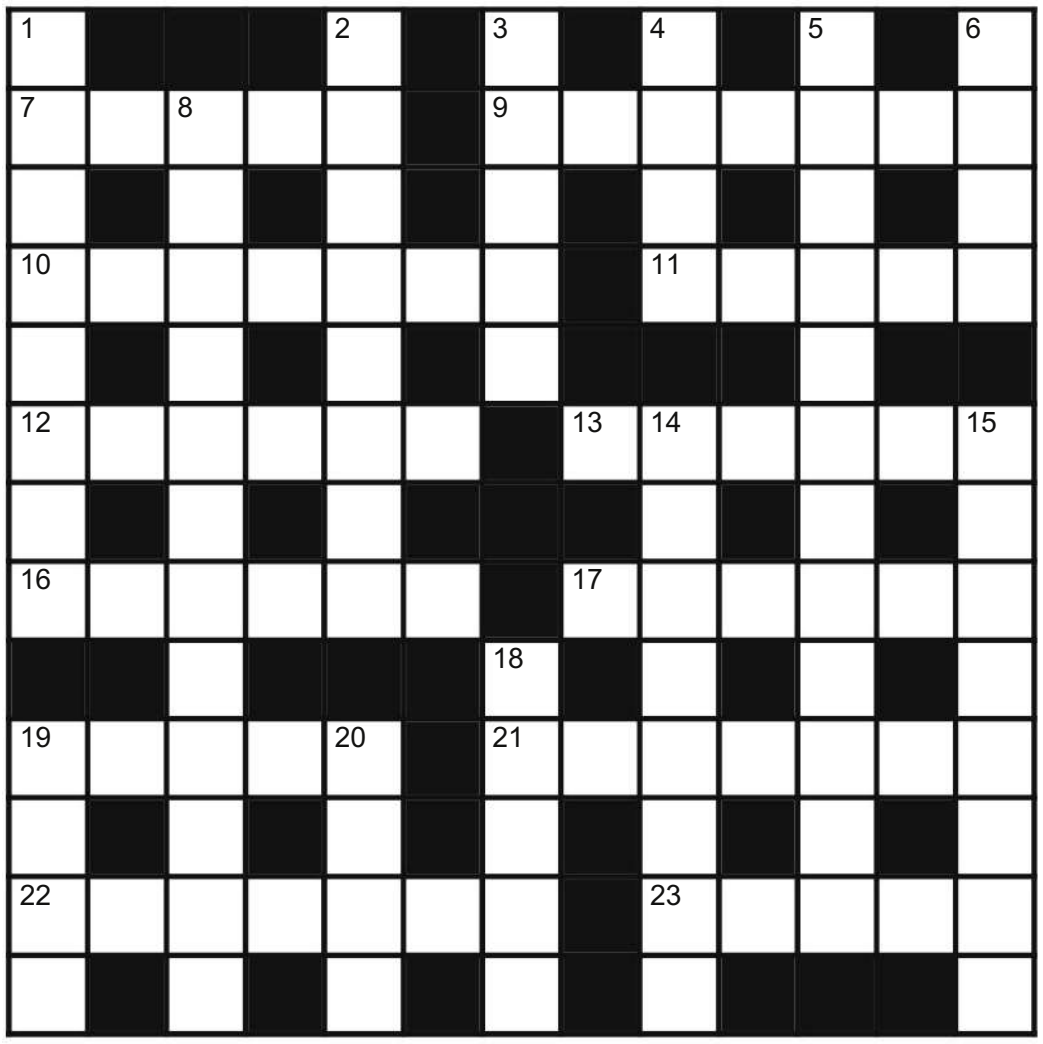
4. Author Terry Pratchett had an unusual form of dementia called posterior cortical atrophy, which affects outer parts of the back of the brain. It may be a sub-category of Alzheimer's or a separate form altogether.

5. Occasionally, dementia can be the side effect of a drug that affects neurotransmitters in the brain – as with certain drugs used to treat insomnia and IBS. Once the medication is stopped, the dementia goes away. SF

ILLUSTRATIONS: MARK FRUDD

CROSSWORD

PENCILS AT THE READY!



ACROSS

7 Peril doesn't start rage (5)
9 Produce notes on organ (7)
10 Criticise each new flamboyance (7)
11 Super design for a bag (5)
12 Sentry to study after battle (6)
13 Sprite upset cleric (6)
16 Enjoy chutney (6)
17 Tom follows lard tycoon (3,3)
19 Fellow finds new diet offensive (5)
21 Somehow rinsed a fish (7)
22 Miser making score go awry (7)
23 Form of green composition (5)

DOWN

1 Workforce might, after Mike's article (8)
2 Their awful jokes are mad (8)
3 Snake is more annoyed without a head (5)
4 Fielder's mistake (4)
5 Exaggeration concerning repeated deed (12)
6 Your gentleman hides desire (4)
8 Officers rushed to shop (7,5)
14 Indignation that gets in the way? (4,4)
15 Teeth changed colour when hitched (8)
18 After lid's removed, cleans sporting trophy (5)
19 Search for a swimmer (4)
20 Doctor seeing work decrease (4)

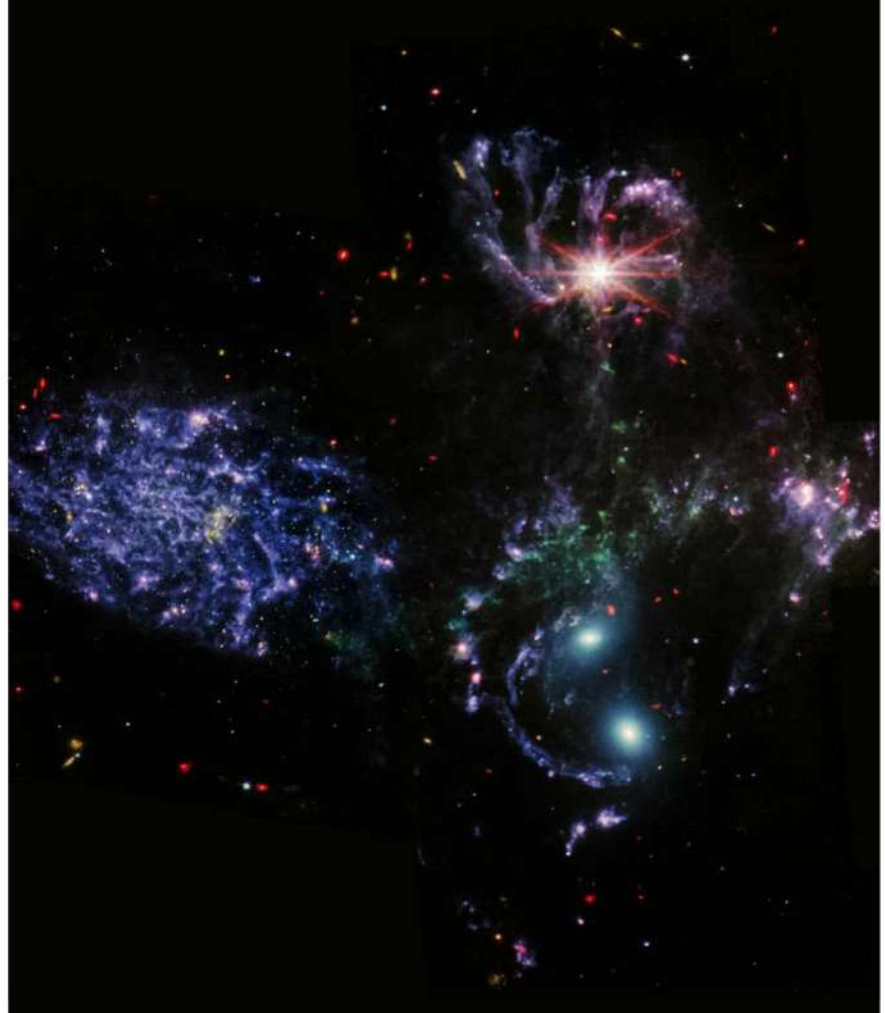
DLR

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

JAMES WEBB: THE BEST IMAGES SO FAR



PLUS

SCIENCE NEWS ROUND-UP

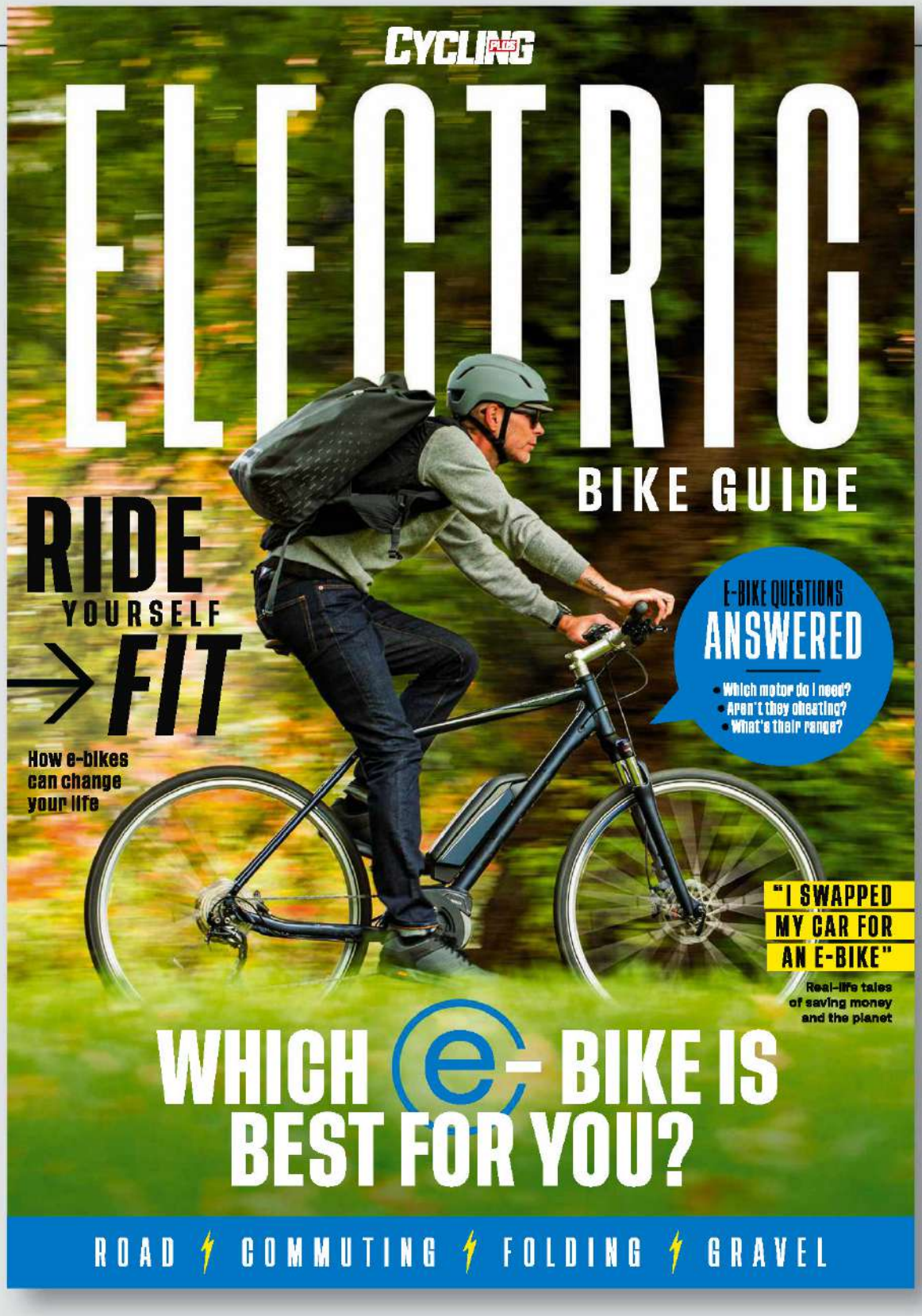
A look back at the biggest stories of 2022.

CHRISTMAS GIFT GUIDE

Still struggling to pick everyone's presents? Our gift guide could help.

ON SALE 7 DEC

SF



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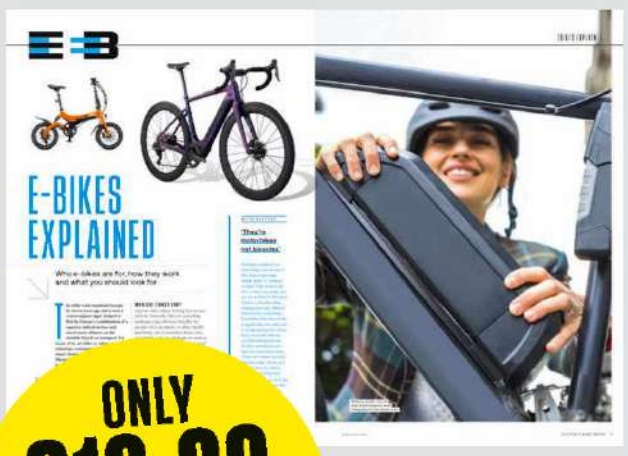

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POPCORN SCIENCE

Could we build underwater cities?

The villain in the new Black Panther film lives under the sea. Could we soon be joining him?

by **STEPHEN KELLY**

The new Black Panther movie *Wakanda Forever* introduces a villain called Namor, a character mainly known for living underwater and ruling the mythical kingdom of Atlantis. Let's ignore the breathing underwater part, and the bit where Atlantis is real, and focus on the fact that Namor's people live in a city deep under the ocean. According to Philip Pauley, a futurist who specialises in promoting the potential of underwater cities, the idea isn't as far-fetched as it sounds.

"The most notable pioneer of underwater habitation was Jacques Cousteau," he says. "He built a number of underwater habitats in the 1970s. These tended to be quite small, but there's nothing stopping us from building something bigger. It would just require time, money and resources."

Pauley's own design for an underwater community, which has attracted interest from film producers and NASA, consists of a central biosphere surrounded by eight smaller biospheres. The dome design "seems obvious", he says. "Water can move around it fairly easily. It can take the biggest amount of pressure. An alternative, more cost-effective shape would be a square, but it would depend on where you want to build your city. Having a current pushing against a flat surface is never a good idea."

Location, adds Pauley, is crucial. A complex built near the surface benefits from easy access to supplies and would be easy to escape, if needed. "Building at a greater depth means more costly, heavy-duty materials," he says. That said, building a structure deeper down does mean that intense water pressure could be used to generate electricity. "It's one way to generate sustainable energy," he says. "A small nuclear reactor is another. You could use surface wave motion, or solar power, or wind turbines. You could use a range of renewables."

Similarly, there are many options for food. "You could take livestock and chickens on board or farm fish," says Pauley. "You could grow meat, become totally vegan or get food brought in." Oxygen, meanwhile, can easily be made from the surrounding water or extracted from the surface.

But Pauley concedes that living deep underwater for long periods may prove psychologically challenging. "There's the issue of isolation," he says. "For mental health, you need sunlight and vitamin D. You can replicate daylight with LED lights but this is another reason to build close to the surface – so people don't feel so cut off from the world."

Pauley sees underwater cities as a way to solve potential issues such as overpopulation, or to provide us with an option in case of a doomsday scenario. "It makes more economic and environmental sense than setting up a colony on Mars, but that's where a lot of the money is going."

Why is that? Pauley's theory is that the ocean is more politicised than space. "It's got so many interested parties: governments, mining and cabling companies, the military, the oil industry. There's a lot going on down there, and they don't want anyone monitoring them!" Or maybe they really have found Atlantis. **SF**

VERDICT

We could build underwater cities! The problem is, entrepreneurs are too preoccupied with sending us to Mars.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

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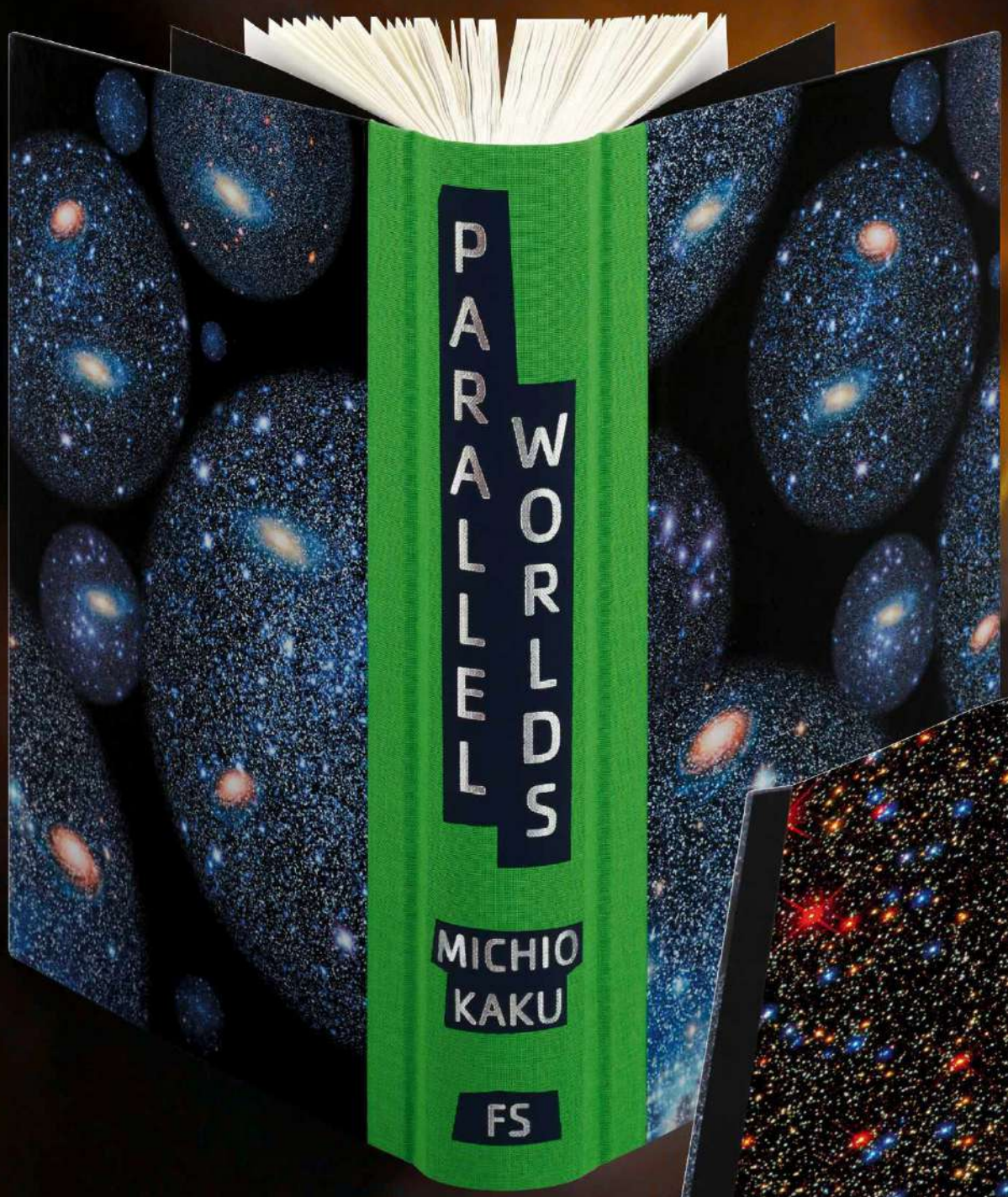

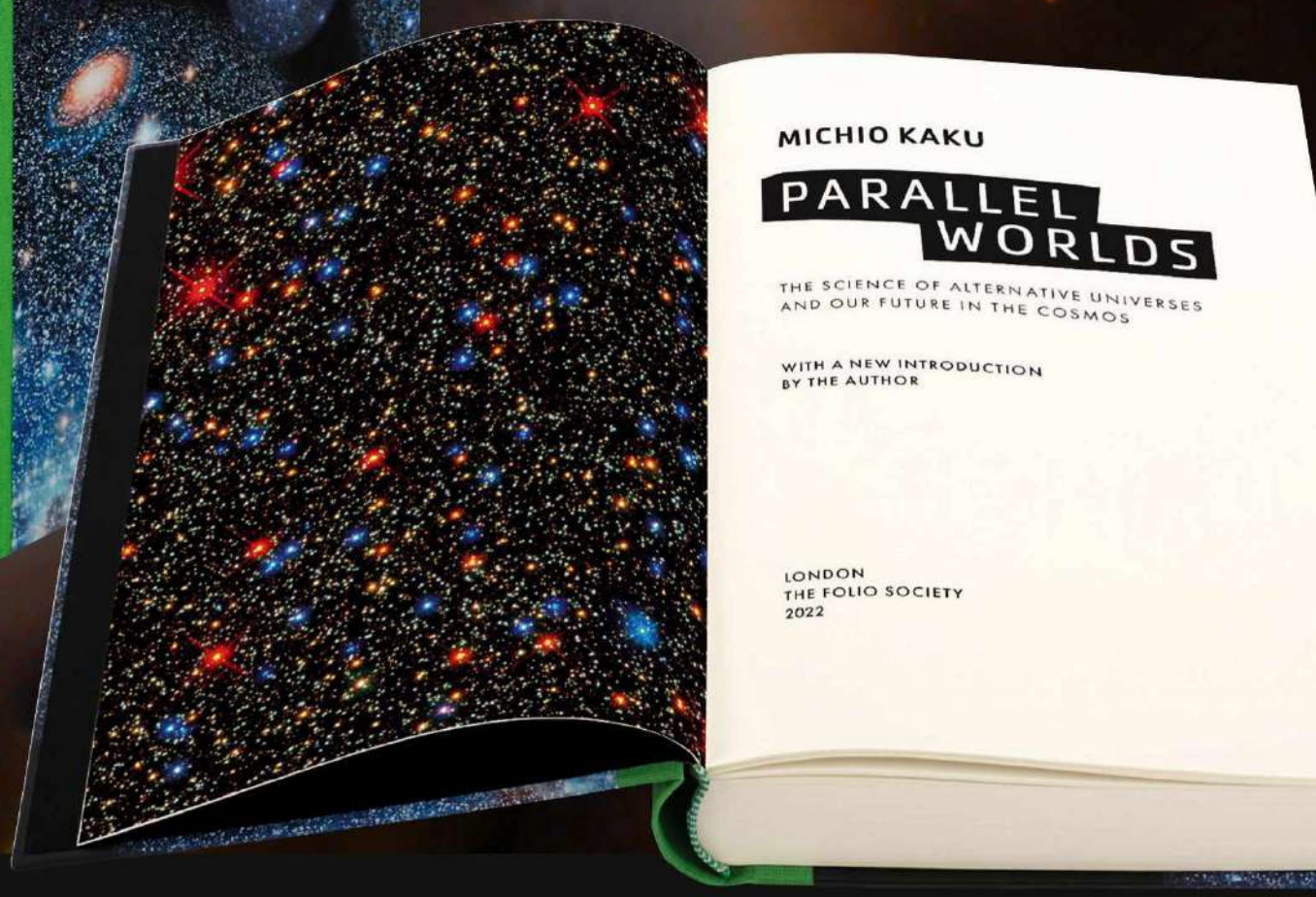

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